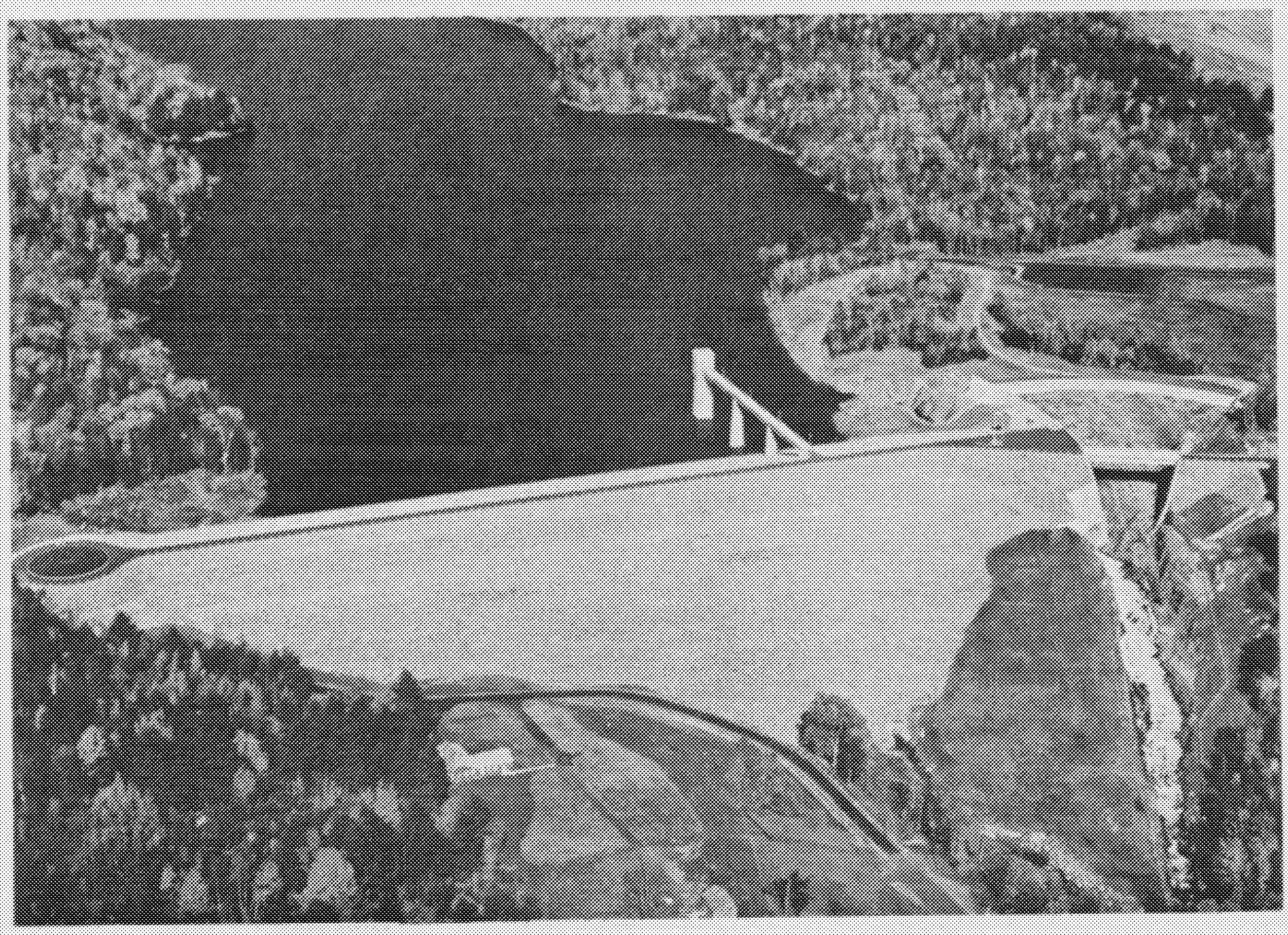
LITTLEVILLE LAKE

MASSACHUSETTS

HYDROPOWER DEVELOPMENT

PRELIMINARY FEASIBILITY STUDY



United States Army
Corps of Engineers
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New England Division

Oct. 1980

LITTLEVILLE LAKE

MASSACHUSETTS

HYDROPOWER DEVELOPMENT

PRELIMINARY FEASIBILITY STUDY

U. S. Army Corps of Engineers
New England Division
Waltham, MA

October 1980

EXECUTIVE SUMMARY

This report has determined that hydropower development at Littleville Lake is feasible and should be investigated further.

The authority for this study is contained in the resolution of the Committee on Public Works of the United States Senate adopted on 11 May 1962 pertaining to the Connecticut River Basin.

Littleville Dam and Reservoir is a multipurpose flood control and water supply Corps facility. It is located in Western Massachusetts on the Middle Branch of the Westfield River in the towns of Huntington and Chester. Construction of the project was completed in 1965. As part of the comprehensive plan for flood protection in the Connecticut River Basin, the project contributes to flood reductions at damage centers on the Westfield and Connecticut Rivers. The water supply storage is for future use by the city of Springfield, as a participant under the provisions of the Water Supply Act of 1958.

A 275-acre lake is maintained to enhance public use and recreation at the level of the water supply pool. The project lands lend themselves to recreational use and afford opportunities for fishing and boating.

Four plans of hydropower development were investigated for Littleville Lake. Of the four plans, one appeared superior to the other three because of minimal project modifications required and its ability to realize a large percentage of the total potential energy of the site.

The recommended plan, Alternative 1, would locate a powerhouse approximately 200 ft. downstream from the toe of the dam. Flows would be passed through the existing 48 inch water supply line to a turbine and discharged to the Middle Branch of the Westfield River. The powerhouse would contain a single 760 kilowatt horizontal Francis turbine capable of discharging 125 cfs under a head of 90 ft. The potential average annual energy generation would be 3,261,000 kilowatt hours at an average plant factor of 0.49.

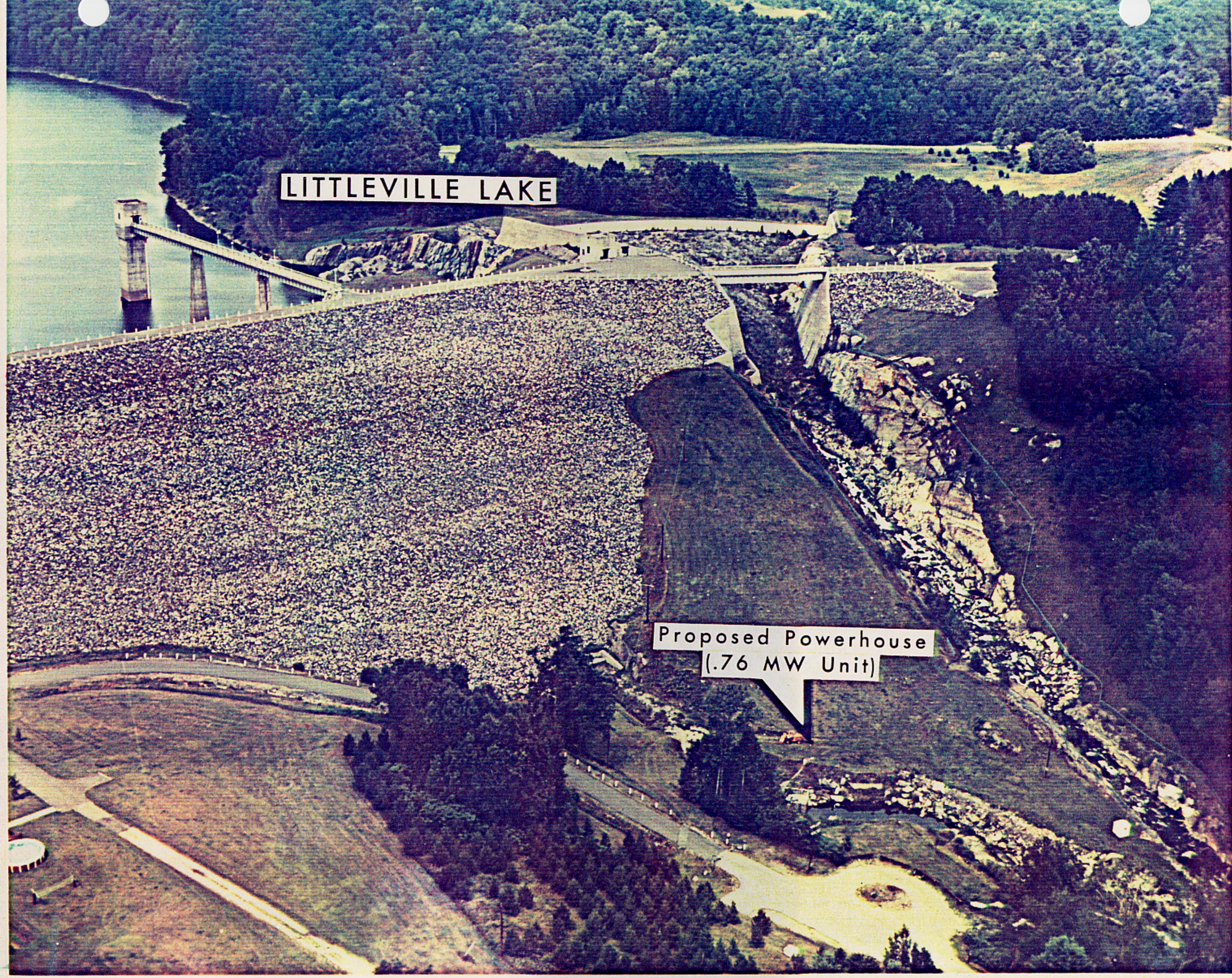
The recommended plan of hydropower development at Littleville Lake is not expected to have any significant environmental impacts. An optimum method of operating the water supply intake structure to balance reservoir and downstream water quality requirements would have to be developed and the extent of the impact of hydropower development on downstream fishery during low flow periods would have to be investigated.

The plan of hydropower development at Littleville Lake would still allow the city of Springfield use of their water supply via the 48 inch water supply line. The Littleville water supply is used as a backup to the existing city of Springfield water supply system during periods of severe drought. Its use in the future during severe droughts would have little effect on the long term average annual hydropower potential.

The construction costs of the recommended plan are estimated to be $1.30 million with annual operation and maintenance of $25,000. The estimated cost of energy would be about 38 mills per Kwh.

Hydropower development at Littleville Lake would have to be viewed generally as a "run-of-river" operation with the energy as "fuel saver". Considering the national energy picture, generation at the site could conserve the equivalent of about 4,600 barrels of oil annually. Expressed in other terms, the 3,261,000 Kwh of annual generation would furnish the equivalent electrical requirement for about 450 homes.

Although hydroelectric development at Littleville Lake would be small in size, it could serve as a demonstration project and would offer the opportunity to develop a clean, renewable source of energy at a reasonable cost.


LITTLEVILLE LAKE
Proposed Powerhouse
(.76 MW Unit)

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1.0 INTRODUCTION

1.1 Scope of Study

This Preliminary Feasibility Study has investigated the addition of hydroelectric power development at Littleville Lake on the Middle Branch of the Westfield River in the towns of Huntington and Chester, Massachusetts.

As Littleville Lake is a multipurpose flood control and water supply Corps project, the plans of hydropower development for the site were those considered to be compatible with the authorized purposes of the Federal project.

1.2 Authority

The authority for this study is contained in the resolution of the Committee on Public Works of the United States Senate adopted 11 May 1962:

> "RESOLVED BY THE COMMITTEE ON PUBLIC WORKS OF THE UNITED STATES SENATE that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved 12 June 1902, be, and is hereby, requested to review the reports of the Connecticut River, Massachusetts, New Hampshire, Vermont, and Connecticut published as House Document Numbered 455, Seventy-fifth Congress, second session, and other reports, with a view to determining the advisability of modifying the existing project at the present time, with particular reference to developing a comprehensive plan of improvement for the basin in the interest of flood control, navigation, hydroelectric power development, water supply and other purposes, coordinated with related land resources."

1.3 Sources of Information

Information used in the preparation of this report was obtained by New England Division personnel from construction drawings and technical information of the Littleville Lake project and from site inspections.

2.0 EXISTING FACILITIES AND BACKGROUND OF LITTLEVILLE DAM

Littleville Dam is located in Western Massachusetts on the Middle Branch of the Westfield River, one mile upstream of its confluence with the main stem of the Westfield River in the towns of Huntington and Chester (See Figure 1). The project was started in 1962 and completed in September 1965.

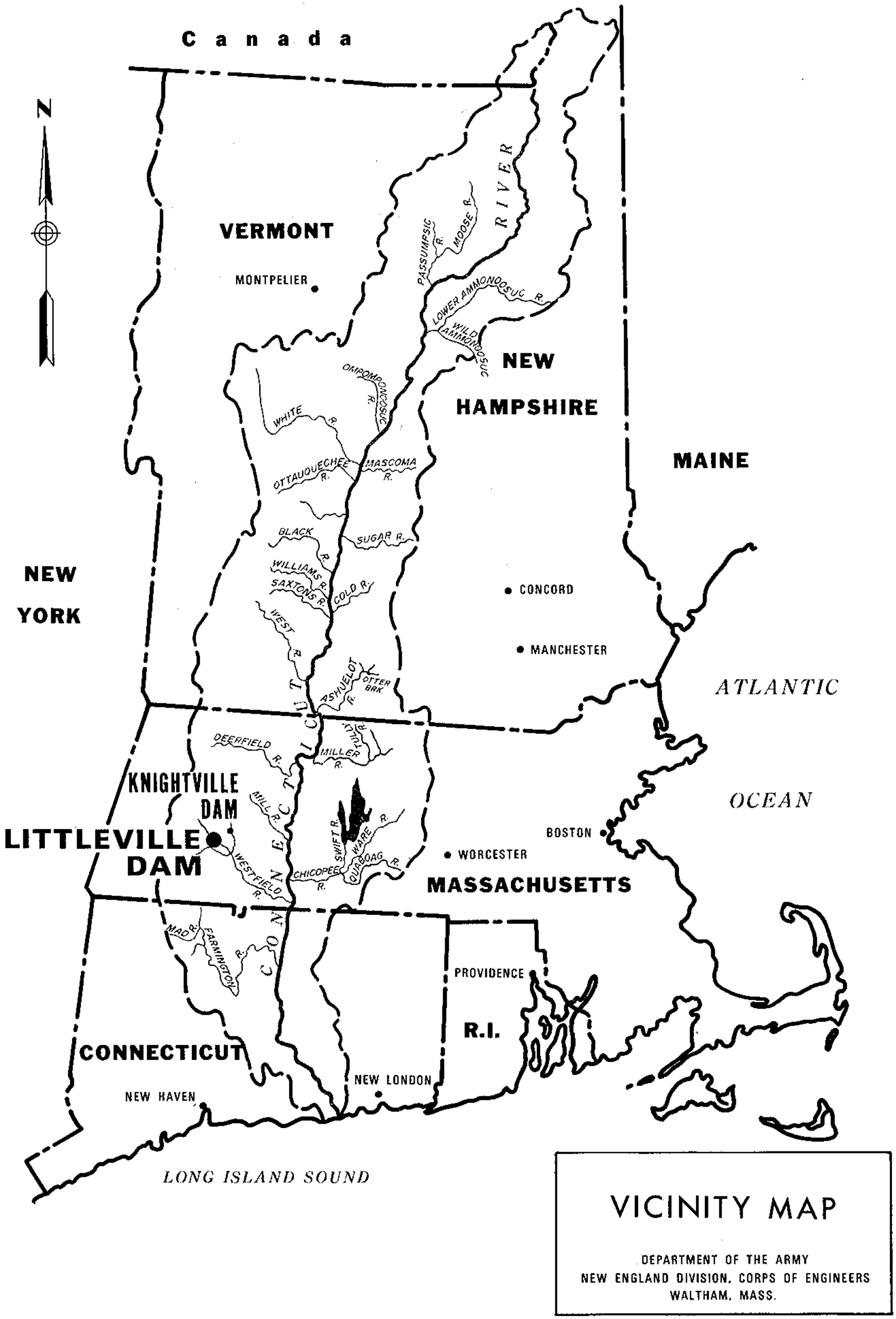
Littleville Dam and Reservoir is a multipurpose flood control and water supply Corps facility. As part of the comprehensive plan for flood protection in the Connecticut River Basin, the project contributes to flood reductions at damage centers on the Westfield and Connecticut Rivers. The water supply storage is for future use by the city of Springfield, as a participant under the provisions of the Water Supply Act of 1958.

At spillway crest, Littleville Reservoir has a total storage capacity of 32,400 acre-feet of which 23,000 are for flood control. The flood control storage is equivalent to 8.3 inches of runoff from the contributing drainage area of 52.3 square miles. A map of the Westfield watershed is shown on Plate 1 (Appendix A). When filled to spillway crest, the reservoir will extend upstream along the Middle Branch for a distance of approximately 3.7 miles and have a surface area of 510 acres. A 275-acre lake is maintained to enhance public use and recreation at the level of the water supply pool. The project lands lend themselves to recreational use and afford opportunities for fishing and boating. A reservoir map of the project is shown on Figure 2.

Important physical components at Littleville Lake consist of a rolled earth dam and dike, a chute spillway composed of a concrete weir, two separate outlet works and storage capacity for both flood control and water supply. A general plan and profile of the dam are shown on Plates 2 and 3 (Appendix A).

The dam embankment consists of rolled earth fill with an impervious core and rock slope protection. It is 1,360 feet in length and has a maximum height above streambed of 164 feet. The top of the dam is at elevation 596.0 feet National Geodetic Vertical Datum of 1929 (NGVD) (formerly mean sea level datum). All elevations used in this report refer to this datum. The spillway is at elevation 576.0 feet which provides 15 feet of spillway surcharge and 5 feet of freeboard. The dam is 25 feet wide at the top and accommodates a paved access road 18 feet in width. The embankment slopes vary from 1 on 3 to 1 on 2.5.

A rolled earth fill dike is located on the left abutment of the dam which closes a natural saddle between the left abutment of the spillway and high ground. The dike is 935 feet long and has a maximum height of 46 feet. The top of the dike is at elevation 596 feet.



Canada
N
VERMONT
MONTPELIER
NEW HAMPSHIRE
MAINE
NEW YORK
CONCORD
MANCHESTER
ATLANTIC
OCEAN
BOSTON
WORCESTER
MASSACHUSETTS
KNIGHTVILLE DAM
LITTLEVILLE DAM
PROVIDENCE
R.I.
CONNECTICUT
NEW HAVEN
NEW LONDON
LONG ISLAND SOUND
RIVER
CONNECTICUT
PASSUMPSIC R.
MOOSE R.
LOWER AMMONOOSUC R.
WILD AMMONOOSUC
OMPOMPANOOSUC R.
WHITE R.
OTTAUQUECHEE R.
MASCOMA R.
BLACK R.
SUGAR R.
WILLIAMS R.
SAXTONS R.
COLD R.
WEST R.
ASHUELOT R.
OTTER BRK.
DEERFIELD R.
MILLER R.
TULLY R.
MILL R.
WESTFIELD R.
SWIFT R.
WARE R.
QUABOAG R.
CHICOPEE R.
MAD R.
FARMINGTON R.
VICINITY MAP
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

FIGURE 1

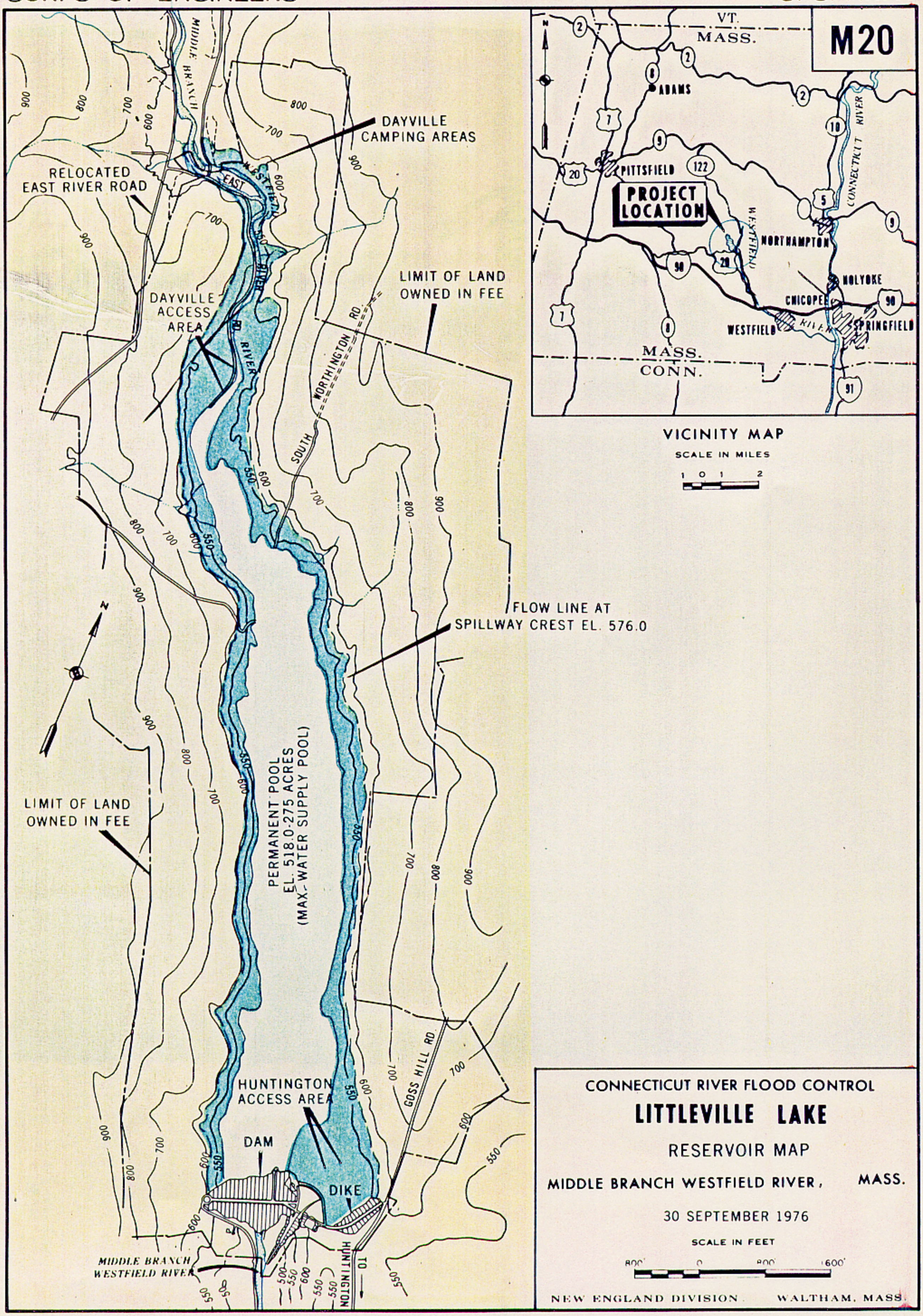

M20
VT.
MASS.
ADAMS
PITTSFIELD
PROJECT LOCATION
NORTHAMPTON
HOLYOKE
CHICOPEE
WESTFIELD
SPRINGFIELD
CONNECTICUT RIVER
WESTFIELD
MASS.
CONN.
VICINITY MAP
SCALE IN MILES
DAYVILLE CAMPING AREAS
RELOCATED EAST RIVER ROAD
DAYVILLE ACCESS AREA
LIMIT OF LAND OWNED IN FEE
SOUTH NORTHINGTON RD.
FLOW LINE AT SPILLWAY CREST EL. 576.0
PERMANENT POOL
EL. 518.0-275 ACRES
(MAX. WATER SUPPLY POOL)
LIMIT OF LAND OWNED IN FEE
HUNTINGTON ACCESS AREA
GOSS HILL RD.
DAM
DIKE
MIDDLE BRANCH WESTFIELD RIVER
TO HUNTINGTON
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE LAKE
RESERVOIR MAP
MIDDLE BRANCH WESTFIELD RIVER, MASS.
30 SEPTEMBER 1976
SCALE IN FEET
NEW ENGLAND DIVISION WALTHAM, MASS.

FIGURE 2

The spillway consists of a concrete ogee weir located on a bedrock plateau on the left bank and a chute type spillway in a bedrock cut. The weir has a length of 400 feet with a crest elevation 576 feet, 7 feet above the approach channel bottom. The discharge channel width varies from 372 feet at the foot of the curved weir to 50 feet at a distance of 440 feet downstream. The total length of the spillway channel is 1,250 feet, with bottom slopes varying from 5 to 21.5 percent. The excavated approach area has a 1 percent slope towards the reservoir.

The Littleville project has two separate reservoir outlet works - one for water supply releases and the other for flood control releases.

The flood control outlet works consist of an intake channel, gates, tower and outlet tunnel. The intake channel is 20-feet wide, excavated in rock to elevation 515 feet. Near the intake structure the channel widens to accommodate a 30-foot concrete weir with crest elevation 518 feet, which is the bottom of the flood control pool and top of the water supply pool. From the weir a concrete-lined channel extends 88.5 feet to the gate structure. Flows are regulated by two 4 x 8 foot wide sluice gates, and discharged through a 370-foot long, 8-foot diameter concrete-lined "horseshoe" tunnel.

The main components of the water supply outlet works consist of a 17.5-foot wide intake channel with invert at elevation 432 feet, an intake structure consisting of a wet well tower with four 36-inch diamater sluice gates at different elevations so that water can be drawn from various levels, an outlet conduit and a 20-foot wide outlet channel. The outlet consists of a 48-inch diameter concrete conduit installed within a 9-foot wide arch-shaped conduit 800 feet in length which was originally used for diversion of the Middle Branch during construction of Littleville Dam.

3.0 ENVIRONMENTAL SETTING

3.1 General

The Westfield River Basin is located in Berkshire, Franklin, Hampden and Hampshire Counties, Massachusetts and a small portion of Hartford County, Connecticut (see Figure 1, Section 2). The basin has a total drainage area of 517 square miles and is the fifth largest subdrainage of the Connecticut River.

The Littleville Dam is located along the Middle Branch of the Westfield River about one mile upstream of its confluence with the main stem in the towns of Huntington and Chester (see Plate 1, Appendix A). The extent of the project area is shown in Figure 2 (Section 2.0).

3.2 Topography

The Westfield River Basin, in general, consists of a maturely dissected upland. Steep-sloped rocky hills are separated by narrow valleys and are drained by many small streams. Watershed elevations range from 2505 feet NGVD at the headwaters of the Westfield River to about 40 feet at the river's confluence with the Connecticut River. The Middle Branch of the Westfield River falls 1,100 feet over its 16 mile length at an average gradient of nearly 70 feet per stream mile. Elevations near the project area ranges from 1,296 feet at the top of Goss Hill (about 2.3 miles north of the damsite) to 432 feet upstream of the damsite.

3.3 Geology

The Westfield River flows in a deep, pre-glacial valley in the New England upland section of western Massachusetts. The bedrock hills and ridges are generally blanketed by a thin cover of glacial till, consisting of unsorted materials deposited directly from the glacier and ranging in gradation from clay to boulders. The bottom of most of the main valleys have been deeply filled by deposits of till and outwash. The outwash deposits, which consist of variable, roughly stratified sand, silt and gravel form narrow floodplains along valley bottoms and terraces on the valley walls. Bedrock outcrops are common through the thin till cover on the upper slopes and tops of the hills. In the valleys, bedrock is exposed only where the rivers have cut through the till and outwash. The bedrock of the region consists of a series of folded Palezoic crystalline rocks, mostly mica schist, of several formations. The folds trend generally north-south.

3.4 Climatology

Annual air temperatures recorded at nearby Knightville Dam for the past 23 years average 45.6^{o} F. Although extremes such as -30^{o}F and 102^{o}F have been recorded, the average January temperature was 23^{o} F; whereas, the average July temperature is 70^{o} F. There is an average of 95 frost free days per year most of which occur between June 3 and September 9.

Annual precipitation averages about 44 inches and is fairly uniform throughout the year. Variations over a 44 year period were as low as 32 inches to as high as 67 inches. Annual snowfall averages 56 inches and intermittently remain on the ground from December through Mid-April.

3.5 Water Quality

The Middle Branch of the Westfield River above Littleville Lake is rated Class A by the Massachusetts Water Resources Commission and as such is designated for use as a public water supply. A designation as to whether this section of the Westfield River is a warm water or a cold water fishery has not been made. Technical requirements for warm water fisheries include a minimum dissolved oxygen concentration (D.O.) of 5 mg/l and a maximum temperature of 83° F. For cold water fisheries the minimum D.O. is 6 mg/l and the maximum temperature is 68° F. Other technical requirements for Class A warm and cold water fisheries include total coliform bacteria not to exceed a log mean of 50 per 100 ml for a set of samples during any monthly sampling period, total dissolved solids not to exceed 500 mg/l, chlorides not to exceed 250 mg/l, sulfates not to exceed 250 mg/l, and nitrate not to exceed 10 mg/l as nitrogen. In addition, there shall be no substances in concentration that: produce objectionable color, odor or turbidity; exceed the limits necessary to control eutrophication; or exceed the recommended limits on the most sensitive receiving the water use.

Downstream from Littleville Lake to the confluence with the Westfield River, the Middle Branch is rated Class B, cold water fishery. Requirements for these waters include a minimum dissolved oxygen concentration of 6 mg/l, a maximum temperature of 68° F, pH in the range 6.5 to 8.0, and fecal coliform bacteria counts not to exceed a log mean of 200 per 100 ml.

There are no significant point-source discharges upstream from Littleville Lake, and the water quality at the project generally meets the requirements of its Class A designation. The water quality data collected by the NED water quality lab since 1970 shows no violation of chloride, sulfate, nitrate or total solids standards; only very rare dissolved oxygen violations, except in the hypolimnion; some coliform violations; and frequent pH and temperature violations. Nutrient analyses show relatively high levels of nitrogen but low levels of phosphorus. Heavy metals concentrations are generally low to undectable except for iron, manganese and zinc. The sources of these metals upstream from the project are unknown. However, iron and manganese levels are increased during the summer by reduction reactions occurring in the hypolimnion in Littleville Lake.

Littleville Lake has a maximum depth of 86 feet, and experiences temperature-induced density stratification during the summer. Dissolved oxygen levels in the hypolimnion are typically less than 5 mg/l and approach anaerobic conditions near the bottom of the lake towards the end of the summer stratification period.

3.6 Aquatic Ecosystem

The 1965 construction of Littleville Dam across the Middle Branch of the Westfield River created a 275 acre lake with an average depth of about 54 feet. During nonflood periods the reservoir is normally kept at a target elevation of 518 feet and contains a volume of about 9,400 acre-feet. The city of Springfield owns the water space between elevation 432 feet and 518 feet under a 1967 agreement with the Corps of Engineers. Because of potential use as public water supply the reservoir bottom was cleared. Besides input from the Middle Branch of the Westfield River, Littleville Lake also receives inflows from four tributaries, including Winchell Brook, which drain from upland wetlands well above the lake elevation.

Water levels fluctuate both daily and seasonally depending on the precipitation. Daily fluctuations rarely exceedone foot. Seasonal fluctuations, however, are more variable. Significant storage, i.e., at least 1 inch of runoff which is equivalent to 2790 acre-feet of flood water, has occurred 17 times since operation began in 1965. The highest storage on record reached an elevation of 548.6 feet in March 1977. About 46% of the storage capacity was used in this event for 3.8 inches of runoff. After such a storage, water levels return to normal in a week's time.

The Littleville Reservoir is a dimictic lake which becomes stratified during the summer and winter months followed by turnover or mixing in the fall and spring. The more marked summer stratification begins in May and becomes more prominent during June. By July and August, the strata are clearly defined with an upper zone (epilimnion) about 5-10 feet thick, a middle zone (metalimnion) ranging from 10-20 feet in thickness, and a lower zone (hypolimnion) extending 50-70 feet above the bottom. This stratification causes a decrease in the dissolved oxygen (D.O.) in the hypolimnion by July. Minimum DO values occur in September. Values from 20-25 feet depth are generally less than 5 parts per million (ppm) which is considered stressful for coldwater fish such as trout. The fall turnover usually occurs by October so that the oxygen levels in the lower stratum are generally above 5 ppm and close to saturation.

The Westfield River was once a migration pathway for Atlantic Salmon. Since the industrial age, degradation of water quality near and below its confluence with the Connecticut River and the installation of 13 dams along the three branches precluded annual spawning runs in this reach of the river. Above the confluence, the river remains a good stream for trout. Most of the reaches are stocked by the Massachusetts Division of Fisheries and Wildlife (MDFW) with the native eastern brook-trout (*Salvelinus fontinalis*); rainbow trout (*Salmo gairdneri*); and brown trout (*Salmo trutta*). Carryover populations of wild brook trout still exist, but the majority of fisherman's take is hatchery bred. Approximately 8,000 rainbow and brown trout are stocked in Littleville Lake each year; whereas, brook trout are stocked upstream and downstream of the lake. Stocking is accomplished during the early spring months.

A number of warmwater species also inhabit Littleville Lake: brown bullhead (Ictalurus nebulosis), yellow perch (Perca flavescens), pumpkin-seed sunfish (Lepomis gibbeosis), bluegill (Lepomis macrohirus), largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieui), white suckers (Catostomus commersoni), and various members of minnow family (Cyprinidae). The MDFW chemically reclaimed the lake in 1965 when the reservoir was being filled. The subsequent appearance of these warmwater species would require periodic reclamation. This is not considered practical by the MDFW due to the large size of the reservoir. Therefore, the MDFW has recently placed more effort in a "put and take" rainbow trout fishery. The lack of oxygen in the hypolimnion during the late summer months reduces the value of Littleville Lake as an adult holding area for coldwater and certain warmwater species.

3.7 Terrestrial Ecosystem

Table 1 indicates the land cover types of the lands held in fee surrounding Littleville Lake based on an intensive 1977 forest inventory. The lake plus the surrounding forest encompasses almost 90% of the entire Federal property. Open woodland and fields are only 9% of this while the remainder of the property includes flood control structures, operation and maintenance areas, access roads and boat ramps. Prior to filling the pool, the reservoir was cleared to elevation 523 feet where the tree line now exists. Below this elevation, perennial grasses, ferns and rock surround the shoreline.

Three known soil associations occur in the study area: (1) Monroe soil - shallow, occurring on steep slopes; (2) Blanford soil - deep, well drained and less stony occurring on plateaus and ridges; and (3) Woodbridge soil - moderately well drained occurring on the lower slopes.

Most of the forest is comprised of second growth northern hardwood and hemlock-hardwood cover types. Common hardwood species include American beech (Fagus grandifolia), sugar maple (Acer saccharum), red maple (Acer rubrum), yellow birch (Betula alleghaniensis), paper birch (Betula papyrifera), white birch (Betula populifolia), red oak (Quercus rubra), American elm (Ulmus americana), and white ash (Fraximus americana). Dominant softwoods include Eastern hemlock (Tsuga canadensis), white pine (Pinus stobus) and red pine (Pinus resinosa). A variety of common northeastern ferns, shrubs and wildflowers occur in the understory.

Forest stands are generally evenaged with nearly 60% mature to overmature or mature within 5 years of rotation. Approximately 14% of the forest in the project area is of pole timber size. The remaining immature stands are reaching saw timber size. Improvements to the growing stock by such techniques as plantings, thinning, pruning and improvement cutting have been proposed in Forest Management Plan, Appendix B of the Littleville Lake Master Plan. Approval of this plan is pending final review. Special management techniques are also being proposed to increase habitat diversity for enhancement of wildlife.

TABLE 1

LAND COVER TYPES SURROUNDING LITTLEVILLE LAKE*

Land Cover Type	Area (Acres)	% Total Area
Forest	1190	73
Lake	273	16
Open Woodland	82	5
Field	61	4
Other**	34	2
Total	1640	100

*Excerpted from Forest Management Plan, Master Plam, Appendix B, Littleville Lake, Huntington, Massachusetts, February 1978, Army Corps of Engineers.

**Flood control structures, operation and maintenance areas, access roads, parking lots and boat ramps.

The forest and regenerating fields serve as habitat for a variety of resident and migrating wildlife. White-tailed deer (Odocoileus virginianus) is the only "big game" species in the area. Typical upland species include varying hare (Lepus americanus), cottontail rabbit (Sylvilagus transitionalis), gray squirrel (Sciurus carolinensis), red squirrel (Tamiasciurus hudsonicus), racoon (Procyon lotor), ruffed grouse (Bonasa umbellus), and American woodcock (Philohela minor). A small number of furbearers such as muskrat (Ondatra Zibethica), mink (Mustela vison), and beaver (Castor canadensis) may also occur in the project area. A variety of typical northeastern small mammals, avifauna, reptiles and invertebrates also inhabit the area.

No hunting or trapping is allowed on project lands because of the potential use of Littleville Lake as a public water supply.

3.8 Rare and Endangered Species

Currently, there are no Federally listed threatened or endangered species residing in the project area (U.S. Fish and Wildlife Service, personal communication). However, the Commonwealth of Massachusetts has compiled a list of State rare and local species which may or may not occur in the area. These species are not Federally listed as threatened or endangered, nor are they proposed. Further study is needed to determine if critical habitat exists in the area.

The Massachusetts State ornithologist indicates that the area may serve as habitat for the great blue heron (Ardea herodias), the Cooper's hawk (Accipiter cooperii), and the sharp-shinned hawk (Accipiter sciatus). Also, the lake chub (Couesius plumbeus), which only occurs in the Westfield River Basin, is currently designated as a species of "Special Consideration." There are a number of mammals, reptiles and amphibians which are also given this designation. Further study is again needed to determine if their habitat does exist in the project area. The Massachusetts Natural Heritage Program has indicated that no rare plants have been presently recorded in the project area.

3.9 Recreational Resources

Littleville Lake is presently operated for water supply and flood control purposes and consists of a 275 acre impoundment with a maximum depth, at the normal water supply pool elevation of 518 feet, of 86 feet at the dam, and an average depth of approximately 54 feet. Fishing is the primary recreational activity that takes place on the lake, and along the shore in designated locations. Sport fishing, primarily for trout, accounts for about 42% of the total recreational visitation at Littleville Lake, while sightseeing, mostly at the dam, accounts for about 50%. Most of the shoreline fishing takes place in the vicinity of the two boat launching ramps at the Huntington Access Area under the dam, and at the Dayville Access Area at the upper end of the lake. Over the past four years sport fishing has averaged about 31,000 visitor days annually. Approximately 60% of this use is recorded at the Huntington Access Area and about 40% at the Dayville Access Area. Littleville Lake is considered an excellent cold water fishery.

3.10 Historic and Archaeological Resources

Prehistoric occupation of the Middle Branch of Westfield River probably consisted of small campsites. These could have been located to obtain seasonally available game, fish or plant resources or stone for tools. The valley would have been a corridor for migratory animals moving between the Connecticut and Housatonic drainages. Prehistoric hunting or trading parties could have followed the same route, and small bands of warriors and refugees may have passed through the area during the Indian Wars of the 17th and 18th centuries.

There are no recorded prehistoric archaeological sites within government property at Littleville Lake. It is possible that small campsites, as described above, existed on the floodplain, while rock shelters on the steep slopes above the valley may have also been temporarily occupied.

Most potential prehistoric site locations on the valley floor were destroyed by dam construction activity such as grubbing, stripping, borrow pit operations and subsequent inundation. The only area of relatively level floodplain now above water is near the northern end of the permanent pool in the vicinity of the northern boat ramp. Neither this area nor the uplands surrounding the permanent pool have been subjected to systematic archaeological survey.

The town of Chester was first settled in the late 18th century. Agriculture formed almost the sole economic base of the town until the second quarter of the 19th century, when the growth of woolen manufacturing and subsequent construction of the railroad began to transform the town into a small industrial center. The continued decline of upland agriculture intensified the shift to a primarily manufacturing economy during the late 19th and early 20th centuries.

The area now occupied by Government property at Littleville Lake was primarily farmland throughout the historic period. Though sheep farming in the early 19th century probably resulted in clearing of most of the area, by the mid 20th century nearly all but the valley floor had reverted to second growth woodland.

The only concentration of settlement was at the village of Littleville, where a small manufacturing community developed. The first gristmill in town was built here in the 1760's. This was followed by a saw and turning mill, shoe shop, cider mill, machine shop, cardboard shop and tannery. All of these were closed by the mid 20th century. The village also had a post office, store, school, church and cemetery. Another cemetery, the Fiske cemetery, was located on East River Road between Littleville and Dayville. All interments from both cemeteries were removed during dam construction and relocated elsewhere.

Nearly all of the historic period sites within present Government property at Littleville Lake are now below the permanent pool and were subjected to grubbing and stripping during dam construction.

Five recorded historic dwelling locations above the permanent pool are subject to frequent inundation probably at least once per year. Two of these sites are near the end of South Worthington Road and three are on East River Road. Four of these dwellings predated 1870, while the fifth dated from sometime between 1870 and 1894. A total of 8 outbuildings were associated with these. The locations of three of these dwellings also have moderate prehistoric site potential, as they are located on the floodplain. The building foundations at these sites were filled during dam construction, and heavy vegetation now obscures their exact locations.

The Fiske Cemetery site has been inundated 8 times since 1967. As the interments were removed, this has had no effect upon any significant cultural resources. Six other dwelling locations are below the dam spillway elevation, but have never been inundated, while 3 more are above spillway crest.

3.11 Socioeconomic Resources

The Westfield River Basin encompasses, either wholly or partially, approximately 30 communities in western Massachusetts. Communities in the northern portion of the watershed are primarily rural and sparsely populated. More concentrated population centers including the cities of Westfield, West Springfield, Holyoke and the town of Agawam, lie in the southern portion of the watershed.

Early development within the basin occurred along the rivers and streams on the eastern slopes of the Berkshires during the mid 1700's. The establishment of grist, saw and paper mills and tanneries characterized early industry. However, due to the rugged terrain throughout the region, expansion of industry was limited to the southeastern portion of the watershed, with the northern communities concentrating on agricultural activities.

Holyoke, with a population of 46,790 in 1975, is the most populated community in the watershed, followed by Westfield with a population of 32,863. All of the communities in the watershed have populations under 10,000. The town of Huntington had a population of 1,730 in 1975, showing a 37.7 percent increase over the preceding 25 years. Chester's population on the other hand, showed an overall decrease of 13.8 percent between 1950 and 1975, although the first five years of the '70's indicated an 8.7 percent increase. Overall, the basin communities have continued to experience population increases with Holyoke the only city to show sustained loss.

Many residents living in the northern portion of the watershed are still engaged in agricultural activities. Other residents commute to jobs in the larger population centers in the Pittsfield and Springfield-Chicopee-Holyoke (SCH) Standard Metropolitan Statistical Area (SMSA). Manufacturing is the largest employment sector in the southern portion of the watershed, although it has experienced a decline in total number employed. Sectors showing increases in employment include the services and finance, insurance and real estate sectors.

4.0 HYDROLOGY

4.1 Hydrologic Characteristics

Littleville Lake is a multipurpose flood control and water supply Corps project located in the Westfield River basin, a tributary to the Connecticut River, in West Central Massachusetts at approximately 42° 16' north latitude and 72° 53' west longitude. The Westfield River has a total watershed area of 517 square miles with Littleville accounting for a drainage area of 52.3 square miles. A map of the Westfield watershed is shown on Plate 1 (Appendix A). A plan and profile of the dam are shown on Plates 2 and 3 (Appendix A).

The Westfield watershed has a cool semihumid climate typical of the New England region. The average annual temperature is about 45 degrees with monthly averages varying from about 69 degrees in July to about 21 degrees in January. Extremes in temperature range from summertime highs in the nineties to wintertime lows in the minus twenties. The mean annual precipitation in the basin is 44 inches occurring quite uniformly throughout the year, generally as periodic storm fronts of 1 to 2 days duration. Average maximum and minimum monthly precipitation, as recorded at nearby Knightville Dam, are listed in Table 2. Much of the winter precipitation occurs as snow with an average annual snowfall of about 56 inches. The snowpack usually reaches a maximum in early March with an average maximum water equivalent of about 4.0 inches.

The Westfield River watershed, the fifth largest tributary area to the Connecticut River, covers a large portion of the eastern slopes of the Berkshires in western Massachusetts. The basin is located within the confines of Berkshire, Franklin, Hampden and Hampshire Counties, with a small portion extending into Hartford County, Connecticut. The watershed has a total drainage area of 517 square miles. Elevations in the watershed vary from 2,505 feet NGVD at Borden Mountain in the headwaters to about 40 feet at the confluence with the Connecticut River in Agawam and West Springfield, Massachusetts. Topography of the upper portion of the Westfield River basin, above the city of Westfield, is rough and rocky and is drained by many small streams which are conducive to rapid runoff. About 2 miles downstream of Westfield the watershed is bisected by a row of hills, Provin and East Mountains, which are a section of the Holyoke range.

The Westfield River has three principal headwater tributaries: the main stem Westfield, Middle Branch and West Branch. Littleville Dam is located on the Middle Branch of the Westfield River, 1 mile upstream of its confluence with the main river. The Middle Branch of the Westfield River originates near the Peru-Worthington town line in northwest Worthington and flows in a southeasterly direction for about 16 miles to its confluence with the Westfield River at Goss Heights in Huntington.

TABLE 2

MONTHLY PRECIPITATION IN INCHES
AT KNIGHTVILLE DAM, MASSACHUSETTS
(Period of Record - 1948 - 1975)

Month	Mean	Maximum	Minimum
January	3.08	6.40	0.75
February	3.18	5.11	1.24
March	3.82	10.18	1.28
April	3.68	5.97	0.82
May	3.54	6.73	0.95
June	3.64	9.12	0.57
July	3.39	7.71	1.12
August	3.69	15.27	1.06
September	3.59	8.06	1.38
October	3.46	16.95	0.42
November	4.36	8.11	0.81
December	4.23	9.38	0.65
Annual	43.61	62.36	32.15

The average annual streamflow in the Westfield basin is about 55 percent of the mean annual precipitation, or 25.7 inches of runoff, equivalent to an average runoff rate of about 2 cubic feet per second (cfs) per square mile of watershed area. Based on 61 years of streamflow records on the Westfield River at Westfield, the maximum annual runoff was 44.1 inches in 1928 and the minimum annual runoff was 11.1 inches in 1965. Though precipitation is quite uniformly distributed throughout the year, the melting of the winter snow cover results in about 50 percent of the annual runoff during the months of March, April and May. Flows are usually lowest during the months of July, August and September.

The USGS gage 01180500 at Goss Heights, Massachusetts is located on the Middle Branch just downstream of Littleville Dam. Because water supply diversion at Littleville has not commenced and the project is operated principally for short term flood control, the monthly flows recorded at the downstream gaging station are representative of the natural monthly streamflow at the project site. A summary of average, maximum and minimum monthly flows recorded at the gage is listed in Table 3. A flow duration curve (discharge rate versus percent of time) for the gage site is shown on Plate 4 (Appendix A).

Littleville Reservoir has a total storage capacity of 32,400 acre-feet between invert elevation 432 feet and spillway crest elevation 576 feet. Of the total storage, 9,400 acre-feet is for backup domestic water supply for the city of Springfield system and the remaining 23,000 acre-feet is flood control storage. The flood control storage is equivalent to 8.3 inches of runoff from the contributing 52.3 square miles of watershed area. The normal pool level of Littleville is elevation 518 feet except during periods of short duration flood regulation. Pertinent data on storages and elevations is listed in Table 4. An area capacity curve for the project is shown on Plate 5 (Appendix A).

4.2 Hydropower Potential

The hydropower potential of a volume of water is the product of its weight and the vertical distance it can be lowered. Water power is the physical effect of the weight of falling water. The function of a water power facility is to transform this gravitational potential energy into mechanical energy, by turning a turbine, for utilization in creating electrical energy via a generator. The potential amount of water power of any stream, river or lake is a function of: (a) the average annual streamflow and (b) the average annual hydraulic head. Both the rate of discharge and the head are quantities which may fluctuate; therefore, it is the magnitude of these two quantities and their variability that determine the potential energy of a site and its dependability.

TABLE 3

AVERAGE MONTHLY FLOWS (1911-1978)
MIDDLE BRANCH AT GOSS HEIGHTS, MASSACHUSETTS
(Drainage Area = 52.6 Square Miles)

Month	Average Flow		Percent of Annual Runoff	Maximum Monthly		Minimum Monthly	
	CFS	Inches		CFS	Inches	CFS	Inches
January	98.3	2.1	7.6	227	5.0	15	0.3
February	89.3	2.0	7.3	247	5.4	17	0.4
March	214.4	4.7	17.1	653	14.3	46	1.0
April	292.9	6.4	23.3	594	13.0	54	1.2
May	136.2	3.0	10.9	280	6.1	35	0.8
June	68.9	1.5	5.5	351	7.7	4	0.1
July	34.3	0.7	2.5	150	3.3	5	0.1
August	32.2	0.7	2.5	316	6.9	3	0.1
September	39.1	0.9	3.3	328	7.2	1	---
October	52.1	1.1	4.0	507	11.1	4	0.1
November	97.0	2.1	7.6	366	8.0	9	0.2
December	107.4	2.3	8.4	351	7.7	18	0.4
Annual	105.1	27.5		182	47.7	43	11.3

TABLE 4

STORAGE - ELEVATION DATA
LITTLEVILLE DAM
(Drainage Area = 52.3 Square Miles)

	Elevation (ft,NGVD)	Stage (ft)	Pool Area (acres)	Storage (ac-ft)	Runoff (inches)
Invert	432	0	0	0	0
Top of Water Supply Pool	518	86	275	9,400	3.4
Spillway Crest	576	144	510	23,000 (net)	8.3 (net)
Maximum Surcharge	591	159	584	31,200 (net)	11.2 (net)
Top of Dam	596	164	-	-	-

The potential rate of power generation, normally measured in kilowatts, is determined by the formula:

$$P = \frac{EHQ}{11.8}$$

where:

P = Power or capacity in kilowatts
E = Combined turbine and generator efficiencies
Q = Rate of discharge in cubic feet per second
H = Net hydraulic head in feet

With today's highly efficient turbines and generators, an average combined efficiency of 80 percent can be reasonably assumed for a typical range of operating head and discharge conditions. The potential amount of power generation over a period of time, "energy", is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

At Littleville there exists a normal pool level at elevation 518 feet, thus providing an existing hydraulic head of about 86 feet. With an average annual flow of 103 cfs, there presently exists a theoretical maximum average annual energy potential at the site of 5261 megawatt hours.

Because of the seasonally low flow character of the Middle Branch and the lack of hydropower storage for seasonal regulation, any hydropower development at the site would have to be viewed generally as a "run-of-river" operation with little dependable capacity and the energy generated evaluated as "fuel saver". Though capacity would not be dependable, it is noted that with a permanent pool, the site would be capable of providing "spinning reserve" capacity for emergency short term generation. It is further noted that the average streamflow in December, the peak electrical demand month, approximates the annual average flow; therefore, average capacity during this peak load month would be equal to the installed capacity at the average annual plant factor.

Also, as part of flood control operations, it is expected that following freshets, a small amount of storage at the project could be used for temporary storage of excess flows to permit use for generation rather than immediate emptying. For purposes of this study, storage capacity equivalent to one-half inch of watershed runoff, was considered potentially available for hydropower regulation.

5.0 PROPOSED ALTERNATIVES

5.1 Description

Four alternatives of hydropower development were investigated at Littleville Lake. Alternative 1 would use the existing 48 inch diameter water supply conduit through the dam as a penstock which would require minimum modifications to the dam. Alternative 2 would involve the installation of a larger water supply conduit for use as a penstock. Alternative 3 would require the installation of a separate penstock extending from the higher level flood control outlet structure to a downstream station. Alternative 4 would add a bascule gate to the spillway to permit raising the permanent pool.

Comparative data for the alternatives is shown on Table 5. Annual cost estimates were based on a 50 year project life and financing at 8 percent interest rate. Project cost estimates were based on information contained in U.S. Army Corps of Engineers Guide Manual: "Feasibility Studies for Small Scale Hydropower Additions", July 1979, updated to 1980 price levels. Because the streamflows at Littleville are relatively small and a small amount of storage capacity could be used for reregulation, all alternatives considered using a single hydropower unit.

Alternative 1 would locate a powerhouse approximately 200 feet downstream from the toe of the dam. Flows would be passed through the existing 48 inch water supply line, then diverted through a turbine and discharged to the Middle Branch of the Westfield River. The normal pool elevation would be raised from the present 518 to 522 feet NGVD, and the storage between these elevations would be used for hydropower regulation. This would provide a 90 foot hydraulic head for power calculations. Assuming maximum permissible velocities of 8-10 feet per second in the conduit, the installed hydraulic capacity was limited to about 125 cfs and the generating capacity to .76 megawatts. With this capacity, average annual generating potential would be 3261 megawatt hours at an estimated comparable cost of 32 mills per kilowatt hour. A sketch of Alternative 1 is shown on Plate 6 (Appendix A).

Alternative 2 is similar to 1 except the 48 inch water line was assumed replaced with a 72 inch diameter penstock to determine if the increased generating capacity and energy output would justify the added cost. This plan would have an installed hydraulic capacity of about 225 cfs and a generating capacity of 1.4 megawatts. Average annual energy generation would be 4062 megawatt hours at an estimated cost of 40 mills per kilowatt-hour. A sketch of this alternative is shown on Plate 7 (Appendix A).

TABLE 5

COMPARATIVE DATA OF THE ALTERNATIVES
LITTLEVILLE LAKE

Alternative	Description	Capacity (cfs)	Capacity (mw)	Head (ft)	Annual Energy (Megawatt Hours)	Comparative Cost (Mills/kilowatt-hour)
1	Tap 48 inch Waterline	125	.76	90	3261	32
2	Replace Waterline with 72 inch line	225	1.1	90	4062	40
3	Independent 7 foot Penstock	300	1.9	90	4490	41
4	Install Bascule Gate	125	1.0	111	4021	149

Alternative 3 would construct a separate 7 foot diameter penstock which would be independent of the existing water supply facilities. It would extend from the higher level flood control outlet works to a hydropower unit located at the downstream toe of the dam. The penstock would be about 375 feet in length. With a hydraulic capacity of about 300 cfs and 90 feet of head, the generating capacity would be 1.9 megawatts. Average annual generation would be about 4,490 megawatt hours at an estimated cost of 41 mills per kilowatt-hour. A sketch of this alternative is shown on Plate 8 (Appendix A).

Alternative 4 would add bascule gates to the spillway to permit raising the normal pool level for hydropower. Adding 10 foot high bascule gates at spillway crest elevation 576 feet would provide added regulating storage and permit the raising of the normal pool 25 feet from 518 to 543 feet. This would provide a hydraulic head of 111 feet. A powerhouse would be located downstream from the toe of the dam and would utilize the existing water supply line. A generating capacity of 1.0 megawatt would be realized with average annual generation of 4,021 megawatt hours at an estimated cost of 149 mills per kilowatt hour. A sketch of this alternative is shown on Plate 9 (Appendix A).

Of the four alternative plans of development at Littleville, Alternative 1 appeared superior to the other three because of minimal project modifications required and its ability to realize a large percentage of the total potential energy of the site. This general plan of development was therefore selected and recommended for further study. This plan, though small in size, appears feasible and could serve as a demonstration project.

During the initial stages of the study, a hydropower diversion from nearby Knightville Dam to Littleville Lake was suggested. Flows diverted by tunnel from Knightville to Littleville would increase flows at Littleville and realize an increased hydraulic head at Littleville over that at Knightville.

Such a plan would require raising Knightville Dam or providing spillway bascule gates so that a pool could be established at an elevation permitting diversion to Littleville. Normal pool at Littleville is presently 518 feet, whereas Knightville is 485± feet.

The downstream invert at Littleville is approximately 432 feet, or about 48 feet lower than Knightville. Therefore, the increased head by diverting from Knightville, rather than hydropower development at Knightville, would be 48 feet less the head loss required for diversion. Assuming generation facilities of a given hydraulic capacity either at Knightville or Littleville would be comparable in cost, then the economics of diversion from Knightville to Littleville would depend on the cost of the diversion facility versus the incremental increased energy benefit due to added head.

Raising Knightville Dam 6.3 feet or providing spillway bascule gates would permit establishing a pool at elevation 532 feet or about 14 feet above the normal pool level at Littleville. A 10 foot diameter diversion tunnel, 7,000 feet in length would have a diversion capacity of about 610 cfs. This diversion capacity would provide an average annual diversion to Littleville of about 255 cfs and with 36 feet net increase in head (48 feet - 12 feet head loss), the incremental increase in annual generation by diversion to Littleville would be 5.47 million kilowatt hours per year.

The cost of a 10 foot diameter concrete lined tunnel, 7,000 feet long, has been estimated to be 9.0 million dollars. The added cost for the added energy would be an estimated 130 mills per kilowatt hour.

Based on the above analogy and current energy values, it was concluded that a plan for hydropower diversion from Knightville to Littleville was not practical.

5.2 Turbine Selection

There are two basic classes of hydraulic turbines - impulse turbines and reaction turbines. The fundamental difference is that impulse turbines are driven by the kinetic energy of a high velocity jet; whereas, reaction turbines, are driven by the combined pressure and velocity of water.

The impulse design has cost-effective operating characteristics for high heads (800 feet and higher) and is not suitable for the Littleville project. Reaction turbines have two basic types of runners - Francis runners and Propeller runners. With the Francis runner, flows enter the runner radially and exit axially; whereas, with the Propeller runner, the flow enters and exists axially. The Francis type runner is more applicable to higher head installations and is usually cost-effective at heads of 100 feet or more. The Propeller runner is more applicable to the lower head-higher discharge installations. It can operate at heads up to 100 feet but is usually most cost-effective at heads of 60 feet or less. A Propeller runner with adjustable blades is known as the "Kaplan" runner. Both turbine types are normally equipped with wicket gates to permit placing the unit on line at synchronous speed, to regulate load and speed, and to shut down the unit. Both the Francis and Propeller turbines can be of a horizontal or vertical design - the axis of the runner being in the vertical or horizontal plane. There are also Propeller turbines of slant design. Both the Francis and Kaplan turbine, equipped with wicket gates can operate quite efficiently under varying discharge from about 40 to 105 percent of design capacity. The Francis unit can operate under varying head from about 60 to 125 percent of design head; whereas, the Kaplan can operate satisfactorily under a range of 60 to 140 percent of design head.

For the installation at Littleville, with a 90 foot head and storage regulating capability, a single horizontal Francis turbine unit was considered most appropriate.

Characteristics of the various turbine types and sizes were obtained from manufacturer literature and from the U.S. Army Corps of Engineers Guide Manual: "Feasibility Studies for Small Scale Hydropower Additions", July 1979.

The selection of turbine size and hydraulic capacity was based on the head and flow characteristics at the site and the hydraulic capacity of existing facilities at the project. The selected capacity adequately harnesses a major portion of the hydropower potential of the site and resulted in a reasonable average annual plant factor. Further optimization of selected installed capacity may result with more detailed design studies. However, use of available "package" type turbine and generator units should provide economies over custom designs.

5.3 Generator Selection

Generators are either synchronous or induction types. The synchronous unit is equipped for self excitation and synchronization before going onto the grid; whereas, the induction generator relies on power from the grid for excitation. Induction generators are somewhat cheaper in cost and more applicable to small installations; however, utility companies are reluctant to having numerous small units in the system capable of draining power from the grid for excitation. Therefore, for this study, a synchronous generator was assumed. Generators would have rated capacities equal to or greater than the rated turbine capacity and also be capable of operating continuously at a 15 percent overload.

6.0 RECOMMENDED ALTERNATIVE

6.1 Pertinent Data

The recommended alternative for hydropower development at Littleville Lake, Alternative 1, would locate a powerhouse approximately 200 feet downstream from the toe of the dam. Flows would be passed through the existing 48 inch water supply line, then diverted through a turbine and discharged to the Middle Branch of the Westfield River. The powerhouse would contain a single 760 kilowatt horizontal Francis turbine capable of discharging 125 cfs under a head of 90 feet. The unit would be equipped with a synchronous generator with not less than 760 kilowatts capacity. The potential average annual energy generation would be 3,261,000 kilowatt hours at an average annual plant factor of 0.49. Computation of the average annual energy is graphically illustrated on Plate 10 (Appendix A). A list of pertinent data is shown on Table 6. A General Plan of Alternative 1, the recommended alternative, is shown on Plate 11 (Appendix A). A plan and section of the powerhouse is shown on Plate 12 (Appendix A).

6.2 Project Operation

The Littleville Lake is presently maintained at elevation 518 feet NGVD with outflow equal to inflow except during periodic flood regulation. Discharges are presently made through the flood control outlet works. Hydropower development would consist of tapping the existing 48 inch diameter water supply line through the dam and using it as a penstock to a small hydro plant located just downstream. Flows would pass through the 48 inch water line, through the turbine for power, and discharge to the river. The proposed plan would still allow the city of Springfield use of their water supply via the 48 inch water supply line. The Littleville water supply is used as a backup to the existing city of Springfield water supply system during periods of severe drought. Its use in the future during severe droughts would have little effect on the long term average annual hydropower potential. The existing Springfield system has an average yield of about 50 MGD (million gallons per day) and a dependable yield of about 37 MGD without Littleville. Present demand on their system is about 37 MGD, with little change over the past several years.

The normal pool would be raised from the present 518 feet to 522 feet, and this infringement on existing flood control storage of 1260 acre-feet would be utilized for hydropower generation. Following flood periods, there is also a possibility that stored floodwaters up to about elevation 527 feet might be temporarily stored (for up to a week) for later generation rather than immediately dumped. This additional infringement on flood control storage, which is equivalent to 1540 acre-feet of storage could produce a potential average annual increase in energy of 465,000 kilowatt hours. It is noted that for the purposes of this study, average annual generation of 3,261,000 Kwh will be used.

TABLE 6

PERTINENT DATA
LITTLEVILLE LAKE
RECOMMENDED PLAN
(Alternative 1)

1.	Number of units	1
2.	Throat diameter (ft.)	2.22
3.	Hydraulic head (ft.)	90
4.	Hydraulic capacity (cfs)	125
5.	Generator type	Synchronous
6.	Generator capacity	760 kw
7.	Potential Annual Generation	3,261,000 kwh
8.	Plant factor	0.49
9.	Turbine/Generator efficiency	80%
10.	Type of turbine	Horizontal Francis

With the planned installation, generating flows would range from a low of about 50 cfs to a high of 131 cfs. Presently, inflows are less than 50 cfs about 50% of the time occurring mostly during mid-summer to late fall. During low flow periods, it is expected that generation would be intermittent, allowing inflow to be stored until sufficient for a period of generation, while still maintaining a minimum required downstream release of 5 cfs. Inflow to the reservoir exceeds 125 cfs about 20% of the time, generally occurring in March and April. During this time, generation would be continuous. Pool fluctuations as a result of intermittent hydropower generation would generally not exceed 4 feet and would be in the 518 to 522 ft. range. Rate of change in the head pool due to "on and off" hydropower operations would be significantly greater during periodic flood regulations.

The proposed hydropower development at Littleville Lake would have to be viewed generally as a "run-of-river" operation with the energy as "fuel saver".

7.0 ENVIRONMENTAL CONSIDERATIONS OF THE ALTERNATIVE

The proposal for harnessing the hydropower potential at Littleville Lake would involve the installation of a powerhouse downstream of the dam. This plan would raise the normal pool from the present 518 ft. elevation to 522 ft. NGVD, thereby, providing a 90-foot hydraulic head for hydropower generation. Fluctuations of the power pool through hydropower operations would be caused by the variations in loading in the plant. Maximum daily fluctuations due to hydropower operations would not exceed one ft./day. Higher seasonal fluctuations due to flood control operations would occur as usual. There is a possibility that following freshets, floodwaters up to elevation 527 ft. might be temporarily stored for release through the turbine. Flood storages above 527 ft. would be released through the flood regulating gates under present flood operation procedures. It is anticipated that water stored for power would not remain in the reservoir longer than for normal flood storage operations. When inflows are low the minimum required downstream release of at least 5 cfs (Massachusetts State Law) would be maintained, and the generator would be operated intermittently with storage regulation between elevations 518 ft. and 522 ft. The extent of the impact of hydropower development on the downstream fishery during low flow periods would be investigated in future studies. A more detailed description of the plan of hydropower development is given in Section 6.0.

Topography, Geology and Climatology

It is not expected that the addition of hydropower to Littleville Lake will have any significant impacts on the topography, geology or climatology of the area. The increased water level and daily fluctuation of the pool will result in minor sloughing of the reservoir shoreline in limited reaches during the first three years of operation, but will stabilize.

Water Quality

The water quality changes caused by hydropower development will depend on what changes are made to the existing impoundment and how it is operated. The proposed plan would raise the pool level about 4 feet to a maximum depth of 90 feet. This would tend to strengthen stratification patterns with the hypolimnion being slightly larger and perhaps slightly colder. Dissolved oxygen and iron and manganese problems could be aggravated. The level of withdrawal would greatly influence stratification and downstream conditions. If cold water is released, the hypolimnion would shrink, and the existing cold water fishery could be adversely affected. Conversely, withdrawing water from the epilimnion would result in a warm water condition downstream. An optimum method of operating the water supply intake structure to balance reservoir and downstream water quality requirements would have to be developed.

Future studies would develop the plan for optimal water quality control and provide predictions of water quality conditions caused by raising the pool.

Aquatic Ecosystem

The main impact on Littleville Lake results from raising of the pool elevation to 522 ft. The proposed action would increase the lake by approximately 15 acres to about 290 acres. This would inundate the present shoreline and the lower portions of the tributaries surrounding the lake including about 420 feet of the Middle Branch. Minor erosion would temporarily increase the amount of suspended solids and nutrients and hence the biological oxygen demand of the lake water around the littoral areas. Primary and secondary productivity may increase slightly, but would return to normal once the lake stabilizes. Substrate instability of the littoral zone may stress aquatic organisms, particularly those which use this area for food or cover. Largemouth bass, which nest in these areas during May and June, may be also affected.

The water supply line would be used for power generation, because it draws from deeper waters than does the flood control outlet. The water supply inverts occur at elevations 447.0, 465.4, 483.8 and 502.2 ft.; whereas, the flood control weir is at 518 ft. The dissolved oxygen, during August and September, is less than 5 ppm below the 500 ft. elevation. Thus, releases made from the three intake gates below this elevation would release the low oxygen water immediately downstream of the outlet works. High oxygen demanding trout in the vicinity may be stressed or killed if exposed to the oxygen deficient waters for a sufficient enough time. Future studies would address an appropriate release plan which would have the least impact on the downstream fishery as well as the lake fishery.

Downstream flows with the addition of hydropower would not be much different than the variations associated with present flood control operations. Release of flood storage is expected to have the same degree of flow variation as with previous events. The addition of hydropower would change the present downstream flow regime under low flow conditions. Low flows (below 50 cfs) do occur in the Middle Branch during July, August and September. (See Table 3, Section 4.0) With the adition of hydropower, the turbines would be shut down when flows fall below 50 cfs until sufficient storage is available. During this time, the required minimum flow would be maintained for the preservation of downstream water quality and fish habitat. When enough storage is available, release through the turbines would increase downstream flow. The extent of the impact of such releases on the downstream fishery during the low flow periods has not been determined.

Construction of the powerhouse in the downstream area would cause disruption of an approximate 200 x 200 ft. section of the streambank and may cause minor siltation in the immediate area. Some material may be carried downstream but would eventually settle in areas of low currents. It is not expected that this would stress downstream aquatic organisms.

Terrestrial Ecosystems

An increase of the pool elevation by four vertical feet for power would inundate approximately 15 additional acres of shoreline and its associated vegetation. The affected vegetation would include perennial grasses, ferns, maple, hemlock, ash and birch. Inundation would probably kill most of these species. To avoid the hazards created by decaying vegetation, past Corps policy concerning the cleaning of shoreline vegetation at hydropower projects has recommended clearing of 3 vertical feet above the target pool elevation (ER 415-2-1). Because the present treeline is at 523 ft., clearing of an additional two feet may be required to accommodate the 522 ft. target pool elevation. Increasing the pool elevation would also raise the ground water elevation around the lake shoreline. Changes in soil saturation levels may have detrimental physiological affects on trees whose roots extend into the raised water table. There may be changes in plant productivity and growth or in susceptibility to disease or windthrow. The latter may alter species composition of trees near the lower portion of the treeline. Some trees are more flood tolerant than others. McKim et al. (1975) found that hemlock, sugar maple, birch and beech are relatively intolerant to flooding during the growing season. Other species such as red and silver maple, white ash and red oak were found to be tolerant to varying degrees. Those species of the former group which occur in the lower portion of the treeline, i.e., that portion which is inundated more frequently for longer periods of time, may not survive. It is expected, in the long term, that the shift in pool elevation would cause a shift in plant species composition in the lower portion of the treeline in favor of more tolerant species.

Upland and furbearing wildlife would be displaced from habitat between 518 and 522 ft. Most would move to higher elevations and resettle although some may perish. The shift may cause overcrowding in some areas where the habitat maximum carrying capacity has been reached. This is not expected to be significant considering the small amount of habitat that would be removed (15 acres).

Rare and Endangered Species

Since there are no currently listed Federal threatened or endangered species in the project area, no impacts are anticipated from implementation of the proposed project. Any state rare or local speccies residing in the project area would receive special consideration according to Massachusetts State Law.

Recreational Resources

An increase in the lake elevation of 4 ft. would inundate both of the heavily used boat launching ramps at Huntington and Dayville which presently provide access to the lake for over 30,000 fishermen annually. The parking area and part of the access road at Dayville would also be subject to inundation as would the turnaround at the Huntington boat ramp. Consequently, to provide adequate access for fishermen to the lake, both boat ramps and the parking area at Dayville should be relocated back from their present locations and extended in order to serve a potential one foot daily lake level fluctuation.

In regard to shoreline fishing at the designated areas near the two boat ramps, the shoreline will be continually changing due to the fluctuating water level which causes an area of exposed shoreline between the water and shore vegetation. However, this probably would not significantly affect fisherman access.

The most significant impact on fishing at Littleville Lake would result from temporarily holding the lake at elevation 527 ft. after flood control operations in order to provide more water for power generation. This would cause the inundation of both relocated boat launching ramps and the parking area at Dayville, and in effect, eliminate fishermen access to the lake until the water level receded to approximately elevation 522 ft., probably in about two days. However, major flood control operations could result in the lake level being held above the 522 ft. elevation for a longer period of time.

Historical and Archaeological Resources

Two historical period farmyard sites on South Worthington Road would be partially inundated by a 522 ft. pool. These sites included two dwellings, two sheds, a barn and a hen coop. Though both dwellings, and probably some of the outbuildings were built before 1870, their remains were bulldozed and filled during construction of Littleville Dam. The only surface indication at these sites today is a dense blanket of weeds and brush outlining the area of disturbance. These sites appear to have been unexceptional examples of rural farmyards, and their present heavily disturbed character indicates that they are unlikely to be eligible for nomination to the National Register of Historic Places.

A small open area near the boat ramp at the northern end of the reservoir would be inundated by a 522 ft. pool. Records indicate that the area below 523 ft. was cleared during dam construction, but this area appears to have been open field at that time, and was probably left undisturbed. This is one of the few level and well drained locations within the valley, and has moderate potential for containing a prehistoric site. Therefore, the area which would be inundated by a 522 ft. permanent pool would be subjected to subsurface testing during the next stage of study for this project. Temporary storage of water during freshets would result in frequent short-term inundation up to 527 ft. As normal flood control operations inundate these areas on a regular basis, no significant change in the effect of this temporary inundation upon cultural resources is anticipated.

Socioeconomic Resources

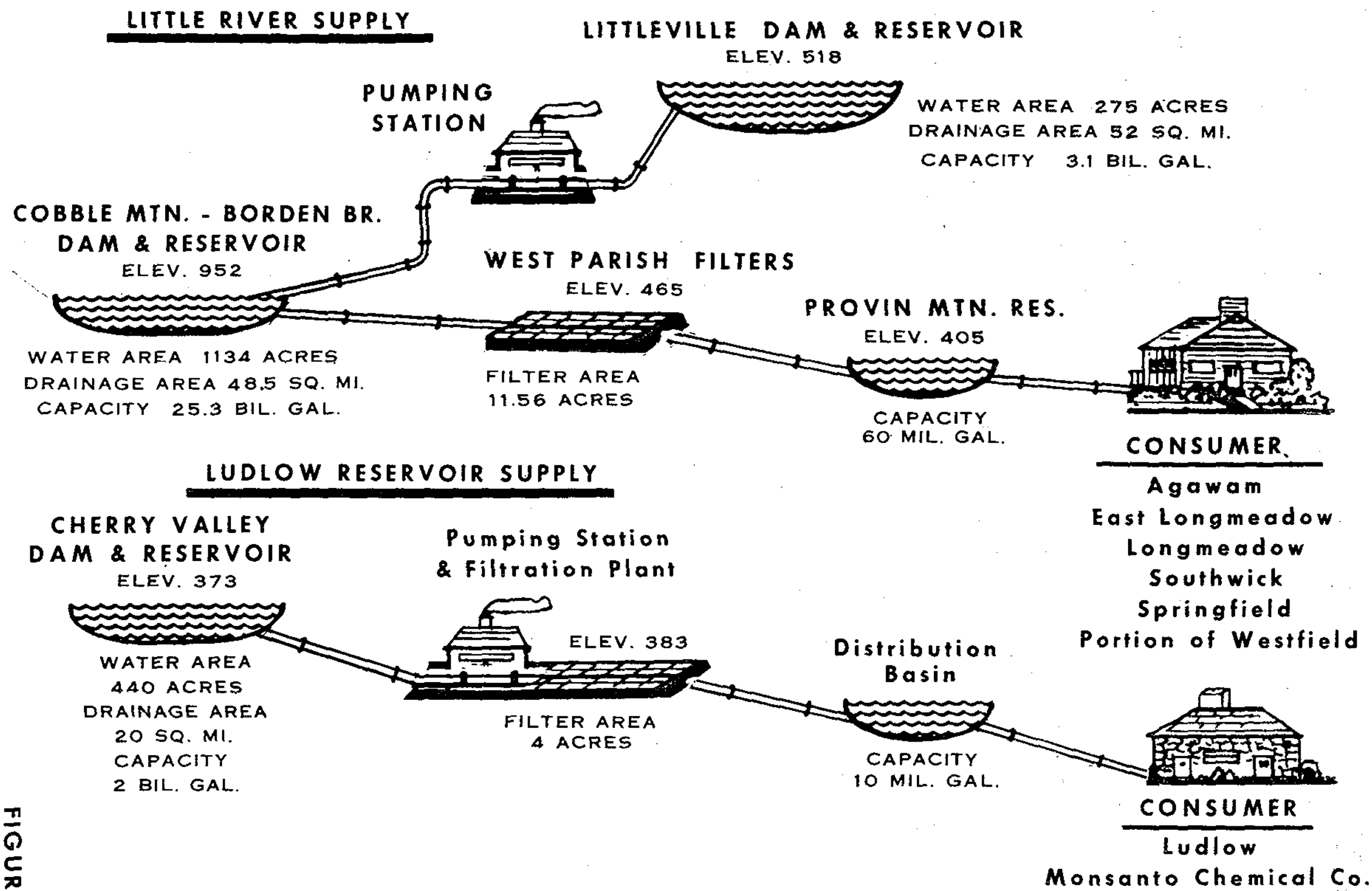
The addition of hydropower to Littleville Lake is not expected to have any significant impacts on socioeconomic resources as the dam and reservoir are already present. The plan of hydropower development would involve only minimal modifications to the existing facilities and is expected to take about 18 months to construct.

8.0 WATER SUPPLY

Littleville Reservoir has a total storage capacity of 32,400 acre-feet between invert elevation 432 ft. NGVD and spillway crest elevation 576 ft. Of the total storage, 9,400 acre-feet is for domestic water supply for the city of Springfield system and the remaining 23,000 acre-feet is flood control storage. The Littleville water supply is used as a backup to the existing city of Springfield water supply system during periods of severe drought. Springfield's water supply system is shown on Figure 3.

In December 1967 the city of Springfield entered into a contract with the Government for water storage space in Littleville Reservoir. A copy of the contract is contained in Appendix B. The terms of the contract gives the city of Springfield the right to utilize storage space between elevation 518 ft. and 432 ft.

As the Littleville water supply is used as a backup to the existing city of Springfield water supply system during periods of severe droughts, its use in the future is expected to have little effect on the long term average annual hydropower potential.



SPRINGFIELD WATER SYSTEM

FIGURE 3

9.0 CIVIL PROJECT FEATURES AND COSTS

9.1 Civil Features

The recommended plan for hydropower development at Littleville Lake (Alternative 1) would locate a powerhouse approximately 200 ft. downstream from the toe of the dam. (See Plates 11 and 12, Appendix A.) The powerhouse would contain a single 760 kilowatt horizontal Francis turbine capable of discharging 125 cfs under a head of 90 feet. The potential average annual energy generation would be 3,261,000 kilowatt hours. A steel penstock would extend from the existing concrete water supply line to the powerhouse. The powerhouse foundation would be cast-in-place concrete on adequate bearing. The powerhouse itself would have structural concrete floors and walls with a steel roof. The exterior concrete would have an architectural finish to blend with the rural surroundings. The tailrace would be excavated in the riverbed. A small cofferdam downstream of the tailrace would isolate the construction from flows in the main channel. Access to the site would be from North Chester Road.

9.2 Construction Schedule

A construction schedule is shown on Plate 13 (Appendix A). A period of four to six months, prior to the start of construction, would be required in order to assure the timely arrival of the required equipment. The actual construction sequence would begin in July since this is the normal dry time of the year and would mean less regulation of dam releases. Once construction begins, work would be continuous with the possible exception of the coldest winter months. The construction period is expected to take approximately 18 months.

9.3 Capital Costs

The capital costs for hydropower development at Littleville Lake has been estimated to be $1.30 million and a breakdown appears in Table 7. Costs listed in the table are based on a July 1980 price level.

TABLE 7

CAPITAL COSTS
LITTLEVILLE LAKE HYDROELECTRIC DEVELOPMENT

	Item	Cost
1.	Turbine/Generator (Horizontal Francis)	$ 370,000
2.	Powerhouse (Civil)	60,000
3.	Miscellaneous Powerhouse Equipment	50,000
4.	Electrical Equipment	160,000
5.	Valves	25,000
6.	Penstock	24,000
7.	Tailrace	45,000
8.	Switchyard	75,000
9.	Transmission Line	39,000
10.	Reservoir Modification	65,000
11.	Reservoir Clearing	30,000
		$ 943,000
	Contingencies	187,000
	TOTAL DIRECT COSTS	$1,130,000
	Engineering and Construction Supervision	170,000
	TOTAL CAPITAL COSTS	$1,300,000

10.0 ECONOMIC ANALYSIS

The purpose of this section is to determine the financial feasibility of the proposed plan of hydroelectric development at Littleville Lake.

10.1 Costs

Total capital costs of hydropower development are estimated to be $1.30 million. A detailed breakdown is shown on Table 7 (Section 9.0). Annual operation and maintenance is estimated to be $25,000/yr. The period of analysis for the project is 50 years. Interest and amortization was computed at 7 3/8% interest rate.

Littleville Lake Power Plant Investment Cost
(1980 Price Level)

Power Facilities Construction	$ 943,000
Contingencies	187,000
Subtotal	$1,130,000
Engineering and Construction Supervision	170,000
TOTAL CONSTRUCTION COST	$1,300,000
(There was no interest during construction charged because the construction period is less than 2 years.)	
TOTAL INVESTMENT COST	$1,300,000

Littleville Lake Power Plant Annual Cost
(1980 Price Level)

Interest & Amortization	$ 99,000
Operation & Maintenance	25,000
TOTAL ANNUAL COST	$ 124,000

The project would produce approximately 3,261,000 kilowatt hours of electricity annually at a cost of about 38.0 mills per kilowatt-hour.

10.2 Benefits

Because this is a preliminary feasibility study and the installed capacity of the project is relatively small, the resource cost of the most likely alternative will not be used as a measure of the benefit to the hydro plant. The project benefit will ultimately be determined by the amount for which the power can be sold. Due to the variability in the cost of energy production, an array of benefits was developed based on a range of possible values for the sale of generated electricity. A range of 40 to 80 mills per Kwh was chosen as appropriate for analysis of benefits. The figure of 40 mills per Kwh is an approximation of the present day value. All benefits were derived by multiplying the annual energy output of the plant by the unit energy value.

The following table summarizes the annual benefits:

Littleville Lake

Head	90 ft.
Installed Capacity	760 KW
Annual Energy	3,261,000 Kwh
Annual Cost	$124,000
Annual Benefit:	
@ 40 mills/Kwh	$130,400
@ 50 mills/Kwh	163,100
@ 60 mills/Kwh	195,700
@ 70 mills/Kwh	228,300
@ 80 mills/Kwh	260,900
Benefit/Cost Ratio:	
@ 40 mills/Kwh	1.05 to 1
@ 50 mills/Kwh	1.32 to 1
@ 60 mills/Kwh	1.58 to 1
@ 70 mills/Kwh	1.84 to 1
@ 80 mills/Kwh	2.10 to 1

10.3 Relative Price Shift Analysis

The Manual of Procedures for Evaluation of NED Benefits and Costs in Water Resource Planning-Level C (Water Resource Council) states that "benefits may vary over the life of a project." One of the chief reasons for this variation (if the most likely alternative to the project is a thermal plant) is real escalation in fuel costs. If it is assumed that the price range of power used in this study is similar to the value of power produced by oil-fired plants, a relative price shift analysis can be undertaken. To ensure efficiency in the use of planning resources for such a small scale hydropower project, this analysis has been undertaken using a very simplistic approach. Despite these simplifications, the relative price shift analysis proves to be a useful tool by emphasizing the increasing cost of fuel which would be displaced by hydropower generation.

The energy price projections employed are those published by the Department of Energy (Federal Register/Vol 45, No 16/Jan. 23, 1980). Fuel prices (distillate, industrial sector) are per million BTU in 1980 dollars for DOE Region I (New England). Projections are annual changes calculated in five-year increments from 1980 to 1995:

Year	Price Per Million BTU's	Energy Price Escalation Rate (% Change Compounded Annually)
1980	6.22	1980 - 1985 : 1.32%
1985	6.64	1985 - 1990 : 1.95%
1990	7.32	1990 - 1995 : 3.66%
1995	8.76	

Approximately 80% of the cost of energy production for a thermal plant is fuel. For purposes of this analysis, 80% of each power value in the range from 40 mills to 80 mills was increased by the appropriate percentage annually to 1995. After escalating the fuel portion, the non-fuel portion (20%) was added back in. The value of 1995 was assumed to exist until the 50th year of project life (2030). Escalated energy values for each year of project life were then discounted and annualized over the 50 year period resulting in a levelized energy value applicable annually. The following table displays escalated energy values at selected years, and the overall levelized energy value:

Escalation of Base Energy Values

Base Value	40 mills	50 mills	60 mills	70 mills	80 mills
Escalated Value @ 1985	42.2	52.7	63.3	73.8	84.3
Escalated Value @ 1990	45.6	57	68.5	79.9	91.2
Escalated Value @ 1995	53	66.3	79.6	92.9	106
Levelized Energy Value	49.6	62.0	74.5	86.9	99.1

The ultimate effect of relative price shift is the increasing of benefits to the hydro project. This is displayed in the following table:

Littleville Lake Economic Analysis

Without Relative Price Shift			With Relative Price Shift		
Energy Value	Total Benefits	Benefit to Cost Ratio	Energy Value	Total Benefits	Benefit to Cost Ratio
40 mills	$130,400	1.05 to 1	49.6	$161,700	1.30 to 1
50	163,100	1.32 to 1	62.0	202,200	1.63 to 1
60	195,700	1.58 to 1	74.5	242,900	1.96 to 1
70	228,300	1.84 to 1	86.9	283,400	2.29 to 1
80	260,900	2.10 to 1	99.1	323,200	2.61 to 1

10.4 Marketability

The electrical energy which would be produced by the project at Littleville Lake would not be sold by the Corps of Engineers. Under Federal law, power generated at Corps projects is marketed by the Department of Energy to public bodies, power cooperatives and private utilities. Although electricity is not sold directly to the consumer, the underlying goal of all Corps hydroelectric projects is to provide power to consumers at the lowest possible rates. Rates are set by the marketing agency and approved by the Federal Energy Regulatory Commission. The marketing agency which serves New England is the Southeastern Power Administration.

10.5 Project Feasibility

The installed capacity of the project is relatively small (760 Kw) as is the level of annual power output (3,261,000 Kwh) when compared to total system load. Therefore, variations in the operation of the project would have little or no impact on the operation of the total power system. In effect, the output of the plant could be classisfied as secondary energy, usable for thermal energy displacement whenever energy is available. At present it is estimated that the project would displace 4,600 barrels of oil annually.

Previous displays in this section have shown benefit-cost ratios above unity for energy values ranging from 40 mills to 80 mills per kilowatt-hour. The inclusion of real fuel cost increase for the thermal alternative reinforces project justification. The summary table below shows that the project is economically justified for all energy values greater than 38.0 mills per Kwh.

Littleville Dam - 760 Kw Plant

Annual Cost	Energy Value	Benefit	B/C Ratio
$124,000	38 mills/Kwh	$124,000	1.00 to 1
124,000	40 mills/Kwh	130,400	1.05 to 1
124,000	50 mills/Kwh	163,100	1.32 to 1
124,000	60 mills/Kwh	195,700	1.58 to 1
124,000	70 mills/Kwh	228,300	1.84 to 1
124,000	80 mills/Kwh	260,900	2.10 to 1

10.6 Interest Rate of Return

In addition to the benefit/cost ratio, another criterion can be employed to assess economic feasibility. This is the "internal rate of return, (IRR). Basically, the internal rate of return is the discount rate at which annual project costs and benefits are equal. The decision criterion is to reject projects whose IRR is less than the expected cost of financing used to implement the project. At present, the interest rate applicable to Federal projects is 7 3/8%. The table below displays the IRR for energy value ranging from 38 to 80 mills/Kwh.

Littleville Lake - Internal Rates of Return

Energy Value	Annual Benefits	Internal Rate of Return
38 mills/Kwh	$124,000	7 3/8%
40 mills/Kwh	130,400	8%
50 mills/Kwh	163,100	10 1/2%
60 mills/Kwh	195,700	13 1/5%
70 mills/Kwh	228,300	15 3/5%
80 mills/Kwh	260,900	18 1/5%

It is apparent from the above table that for energy values greater than 38 mills, the project will have a percentage rate of return greater than the cost of financing.

11.0 CONCLUSION

This report has determined that hydropower development at Littleville Lake is feasible and should be investigated further.

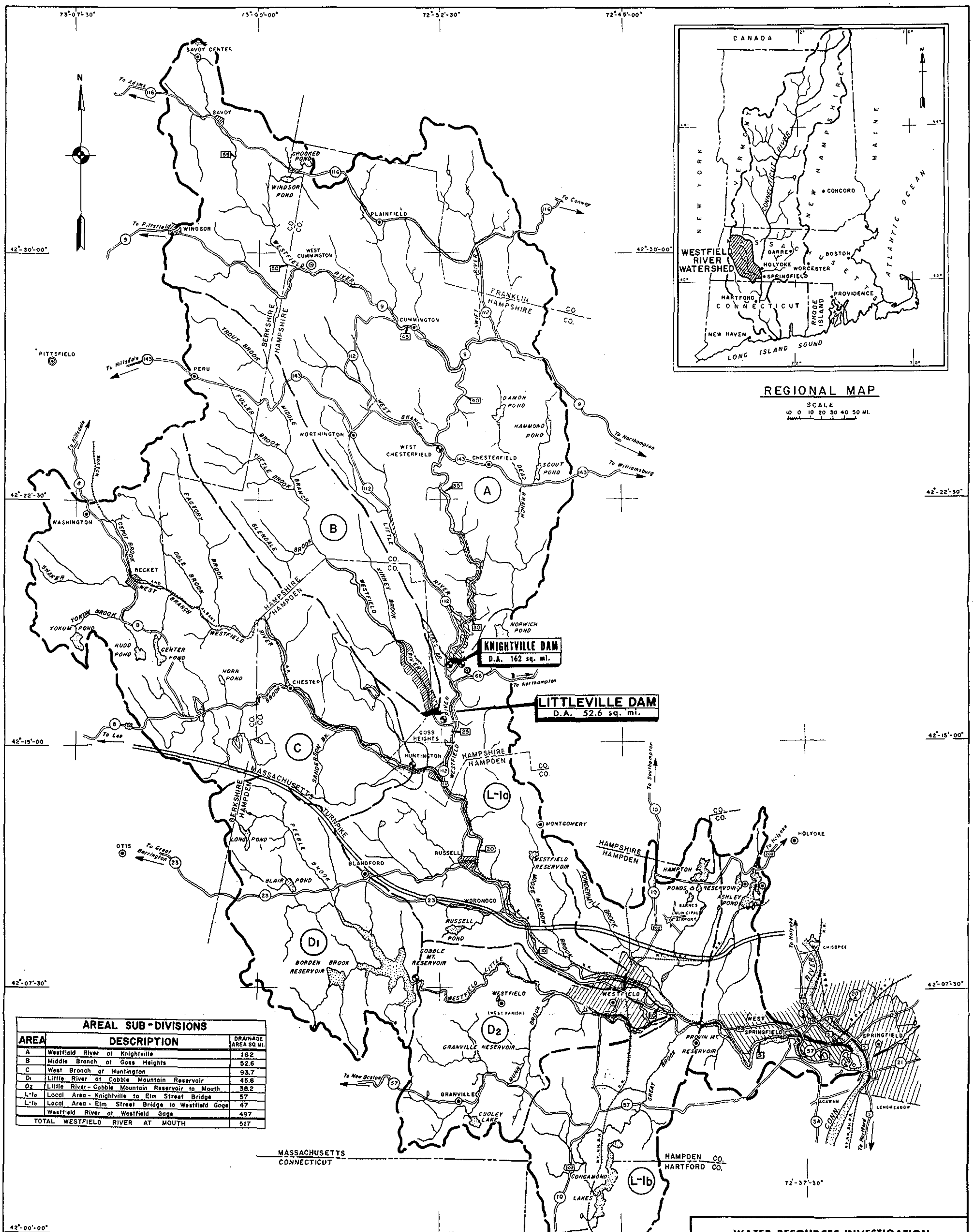
Four alternatives of hydropower development were investigated for Littleville Lake. Of the four plans, Alternative 1 appeared superior to the other three because of minimal project modifications required and its ability to realize a large percentage of the total potential energy of the site.

The recommended plan, Alternative 1, would locate a powerhouse approximately 200 ft. downstream from the toe of the dam. (See Plate 11, Appendix A). Flows would be passed through the existing 48 inch water supply line to a turbine and then discharged to the Middle Branch of the Westfield River. The powerhouse would contain a single 760 kilowatt horizontal Francis turbine capable of discharging 125 cfs under a head of 90 ft. The potential average annual energy generation would be 3,261,000 kilowatt hours at an average annual plant factor of 0.49.

Total construction costs are estimated to be $1.30 million with annual operation and maintenance of $25,000. The estimated cost of energy would be about 38 mills per Kwh.

Although hydroelectric development at Littleville Lake would be small in size, it could serve as a demonstration project and would offer the opportunity to develop a clean, renewable source of energy at a reasonable cost.

APPENDIX A - Plates



AREAL SUB-DIVISIONS

AREA	DESCRIPTION	DRAINAGE AREA SQ. MI.
A	Westfield River at Knightville	162
B	Middle Branch at Goss Heights	52.6
C	West Branch at Huntington	93.7
D_1	Little River at Cobble Mountain Reservoir	45.8
D_2	Little River - Cobble Mountain Reservoir to Mouth	38.2
L-1a	Local Area - Knightville to Elm Street Bridge	57
L-1b	Local Area - Elm Street Bridge to Westfield Gage	47
	Westfield River at Westfield Gage	497
TOTAL WESTFIELD RIVER AT MOUTH		517

WATER RESOURCES INVESTIGATION
CONNECTICUT RIVER BASIN

WESTFIELD RIVER WATERSHED

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 1

CORPS OF ENGINEERS U.S. ARMY

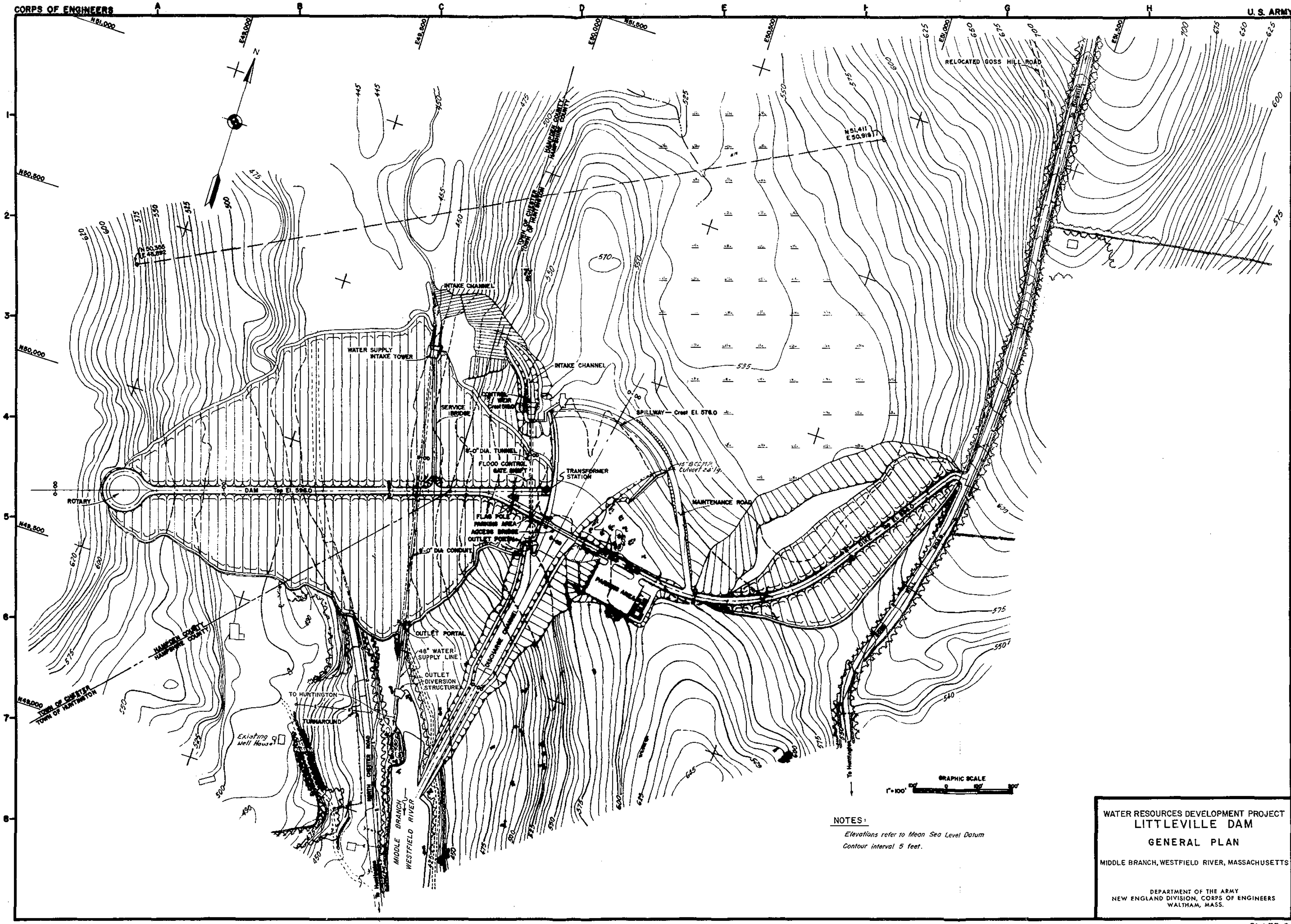
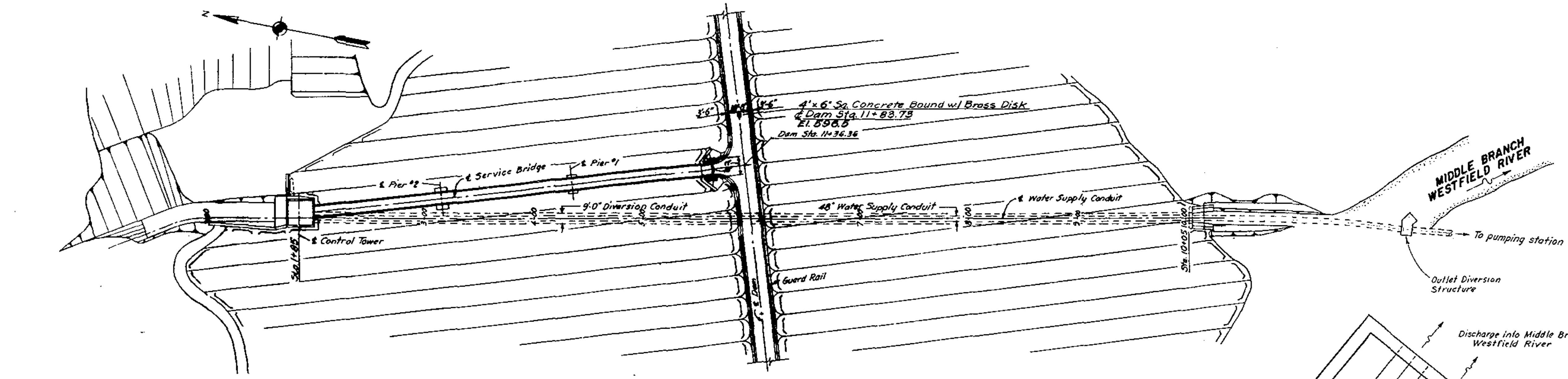
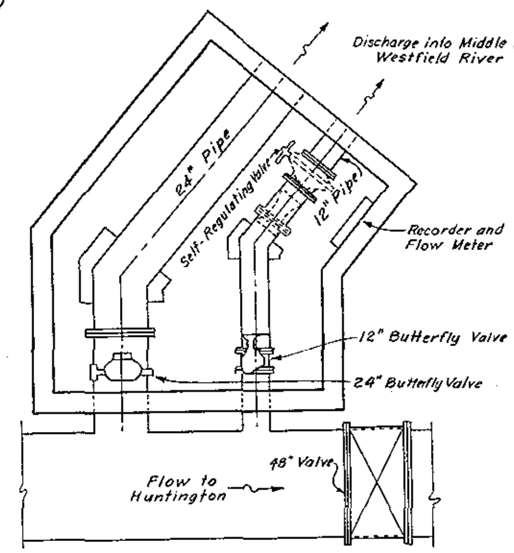


PLATE 2



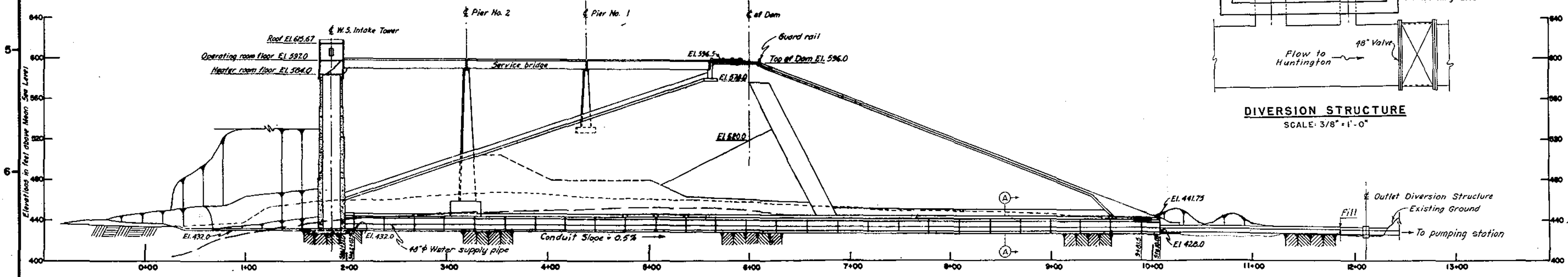
PLAN

SCALE: 1" = 40'



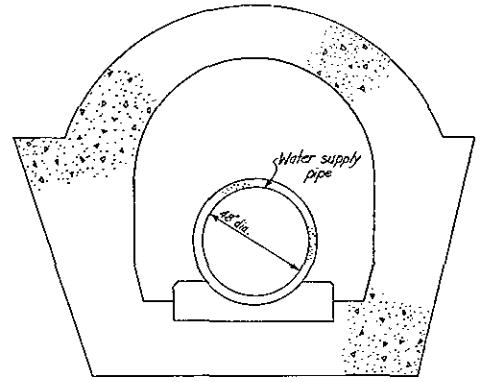
DIVERSION STRUCTURE

SCALE: 3/8" = 1'-0"



PROFILE ALONG ℄ CONDUIT

SCALE: 1" = 40'



SECTION A—A

SCALE: 3/8" = 1'-0"

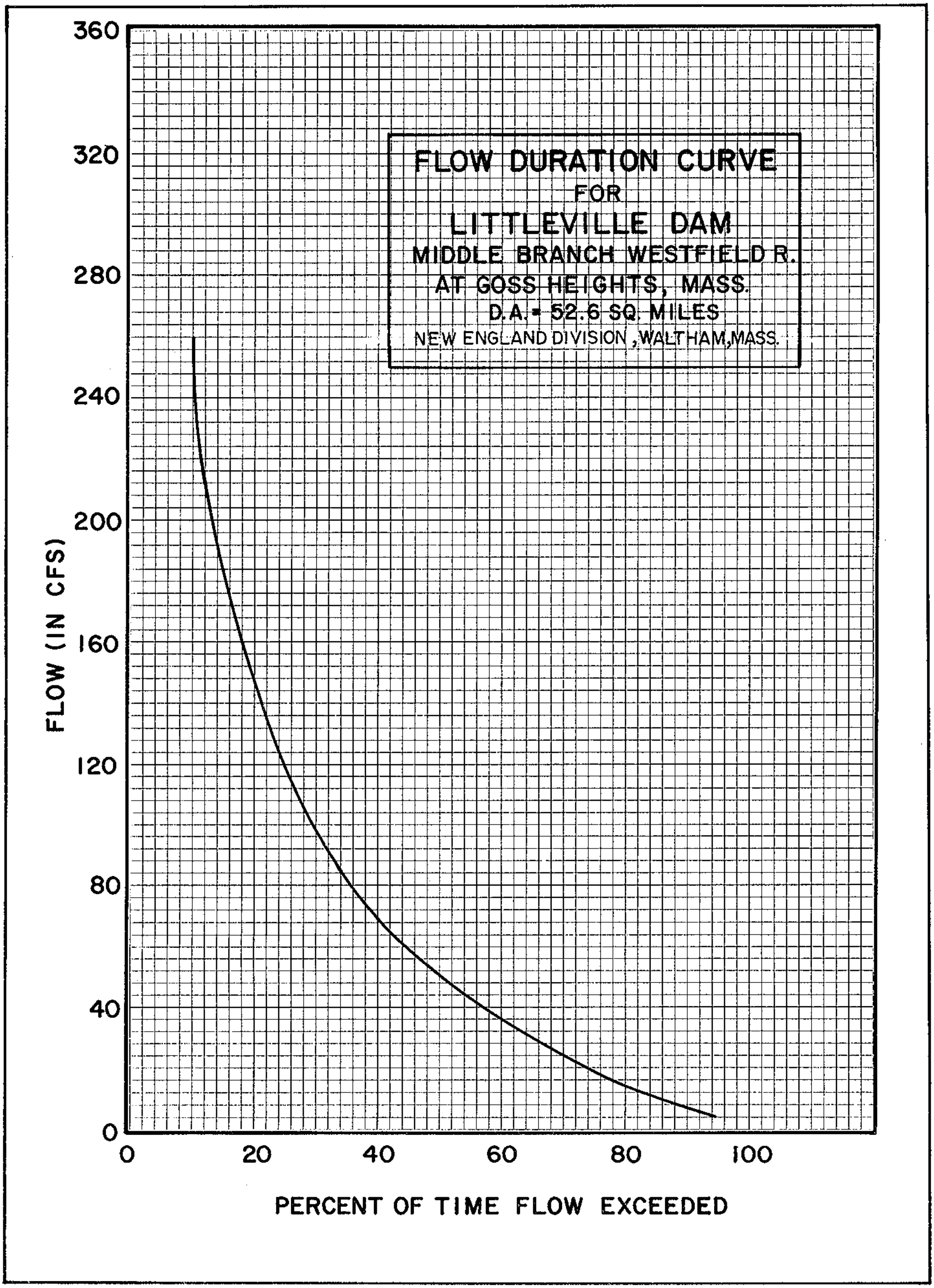
GRAPHIC SCALE 1" = 40' 40' 0 40' 80'

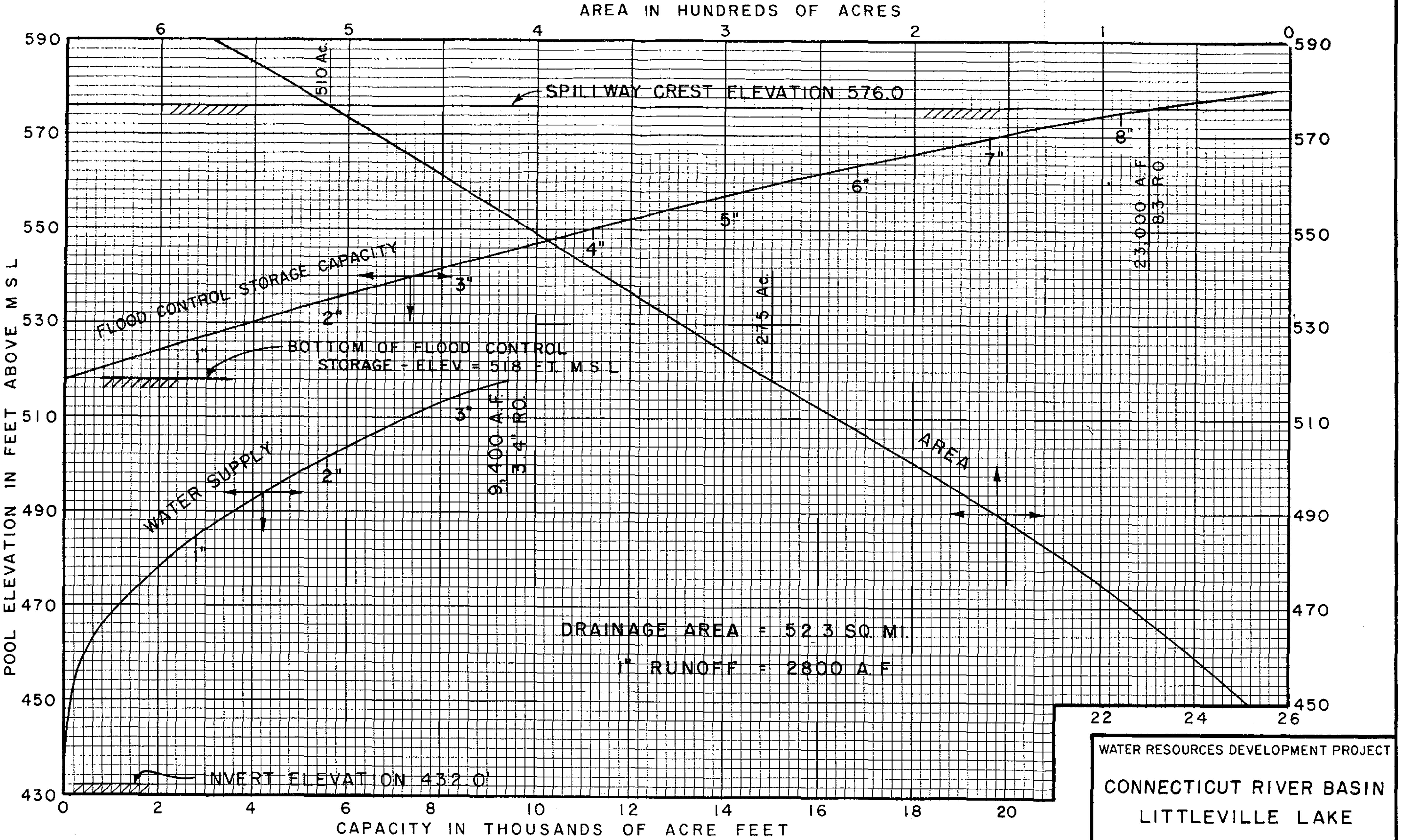
NOTE:
All elevations refer to NGVD

CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
WATER SUPPLY & SERVICE BRIDGE
PLAN AND PROFILE

MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.


FLOW DURATION CURVE
FOR
LITTLEVILLE DAM
MIDDLE BRANCH WESTFIELD R.
AT GOSS HEIGHTS, MASS.
D.A. = 52.6 SQ. MILES
NEW ENGLAND DIVISION, WALTHAM, MASS.
FLOW (IN CFS)
360
320
280
240
200
160
120
80
40
0
0
20
40
60
80
100
PERCENT OF TIME FLOW EXCEEDED



WATER RESOURCES DEVELOPMENT PROJECT

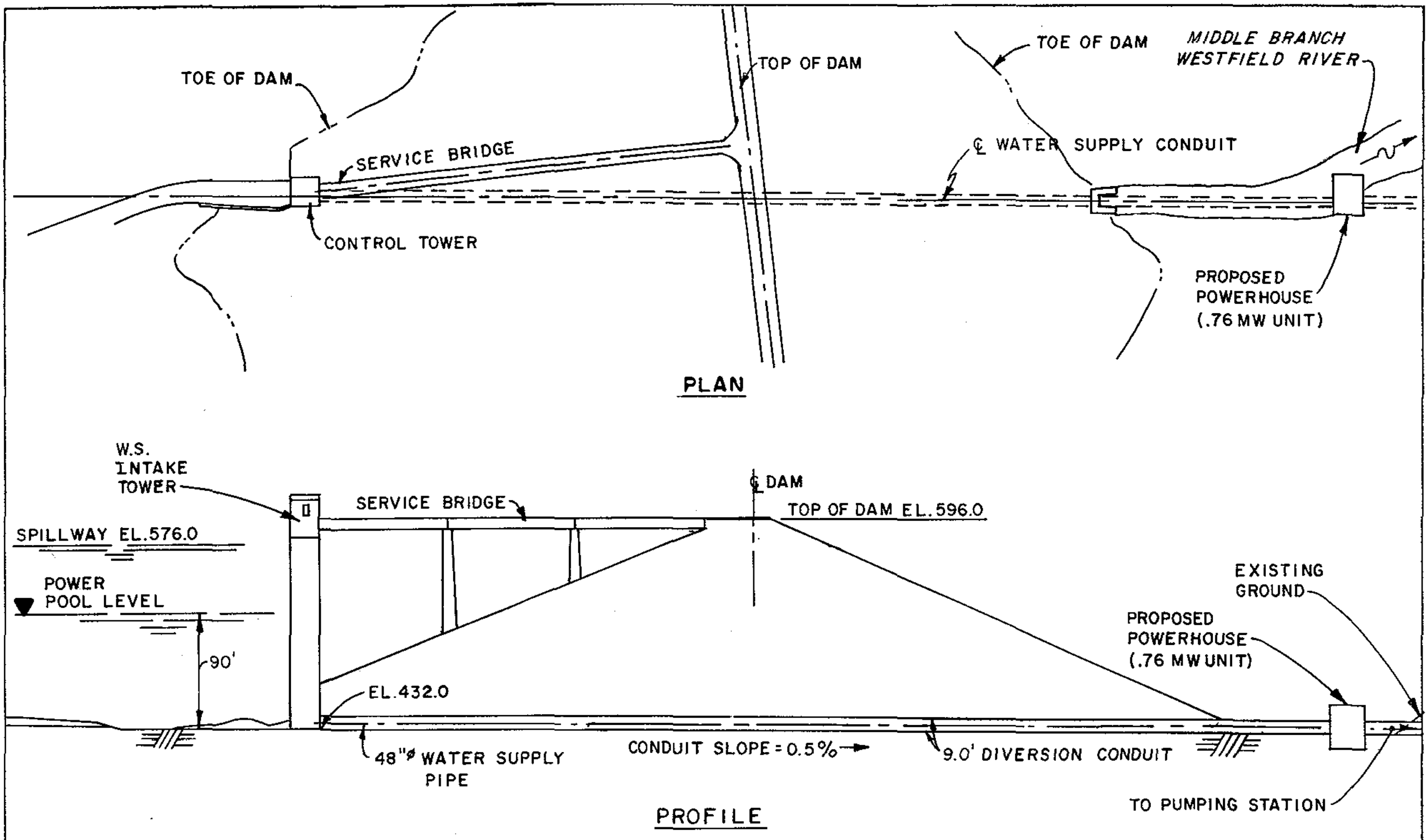
CONNECTICUT RIVER BASIN

LITTLEVILLE LAKE

AREA & CAPACITY CURVE

NEW ENGLAND DIVISION, WALTHAM, MA.
SEPT. 1976

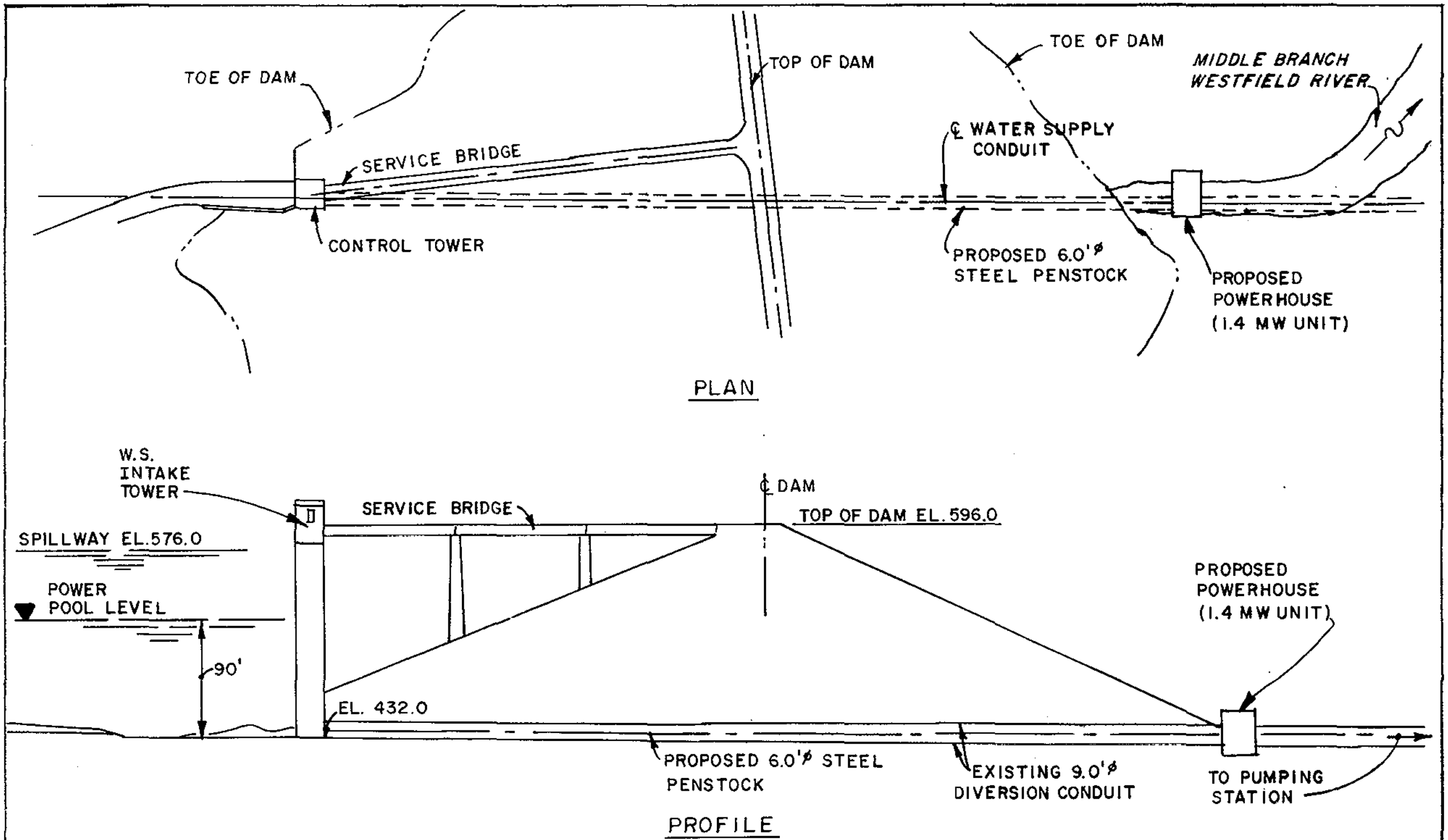
PLATE 5



LITTLEVILLE DAM
ALTERNATIVE #1

NEW ENGLAND DIVISION, WALTHAM, MA.

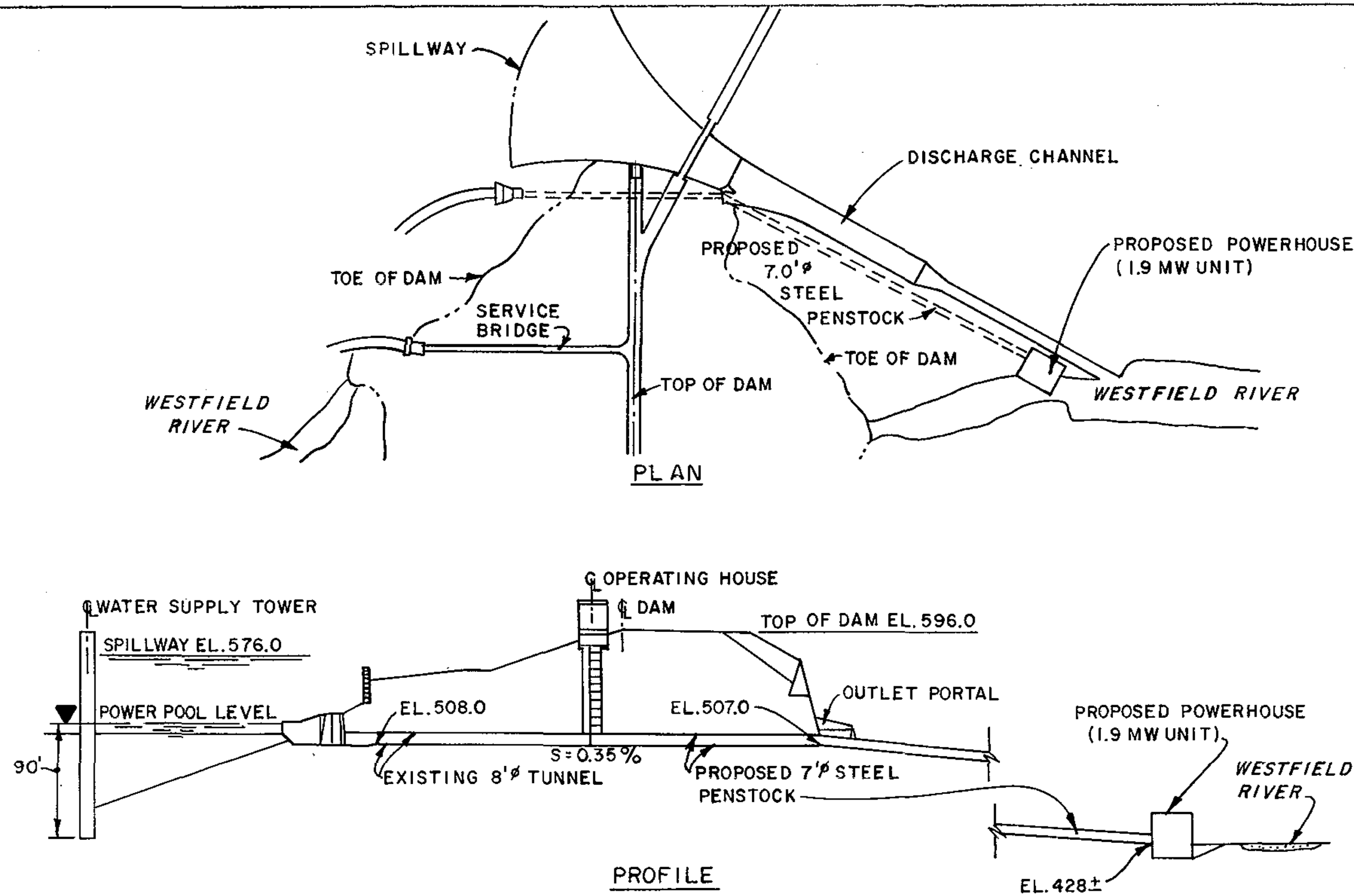
PLATE 6



LITTLEVILLE DAM
ALTERNATIVE #2

NEW ENGLAND DIVISION, WALTHAM, MA.

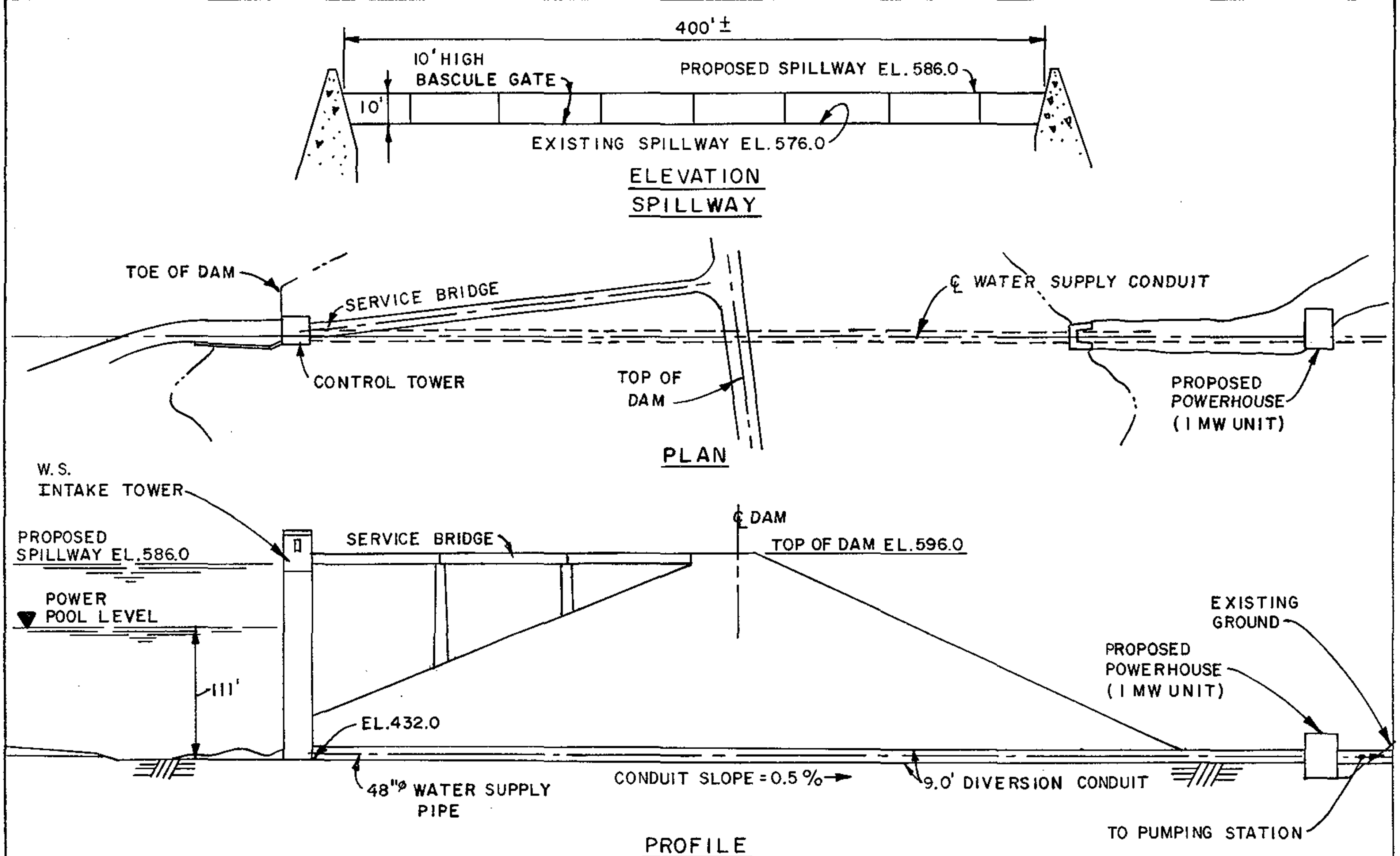
PLATE 7



LITTLEVILLE DAM
ALTERNATIVE #3

NEW ENGLAND DIVISION, WALTHAM, MA.

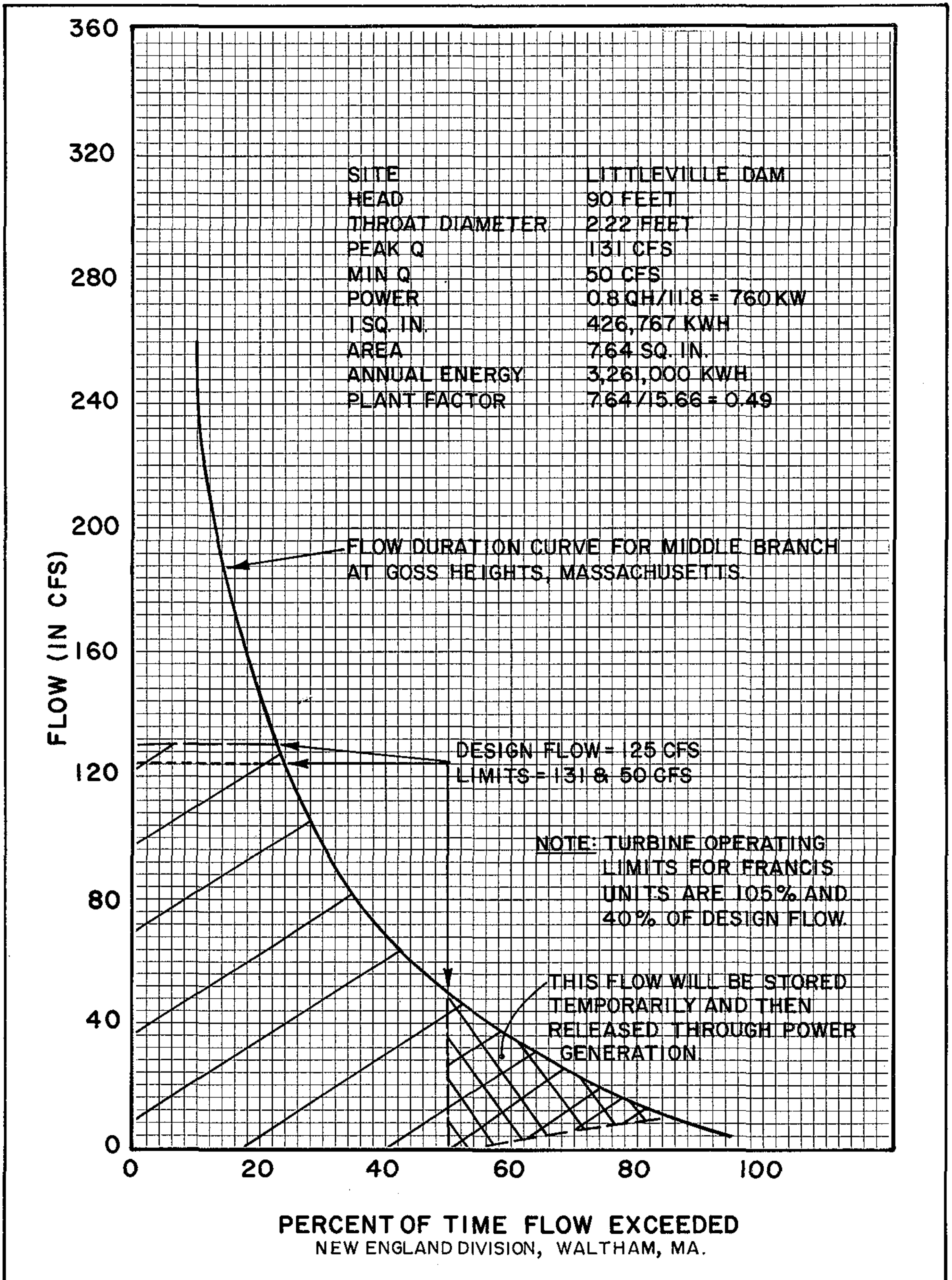
PLATE 8



LITTLEVILLE DAM

ALTERNATIVE #4

NEW ENGLAND DIVISION, WALTHAM, MA.



NEW ENGLAND DIVISION, WALTHAM, MA.

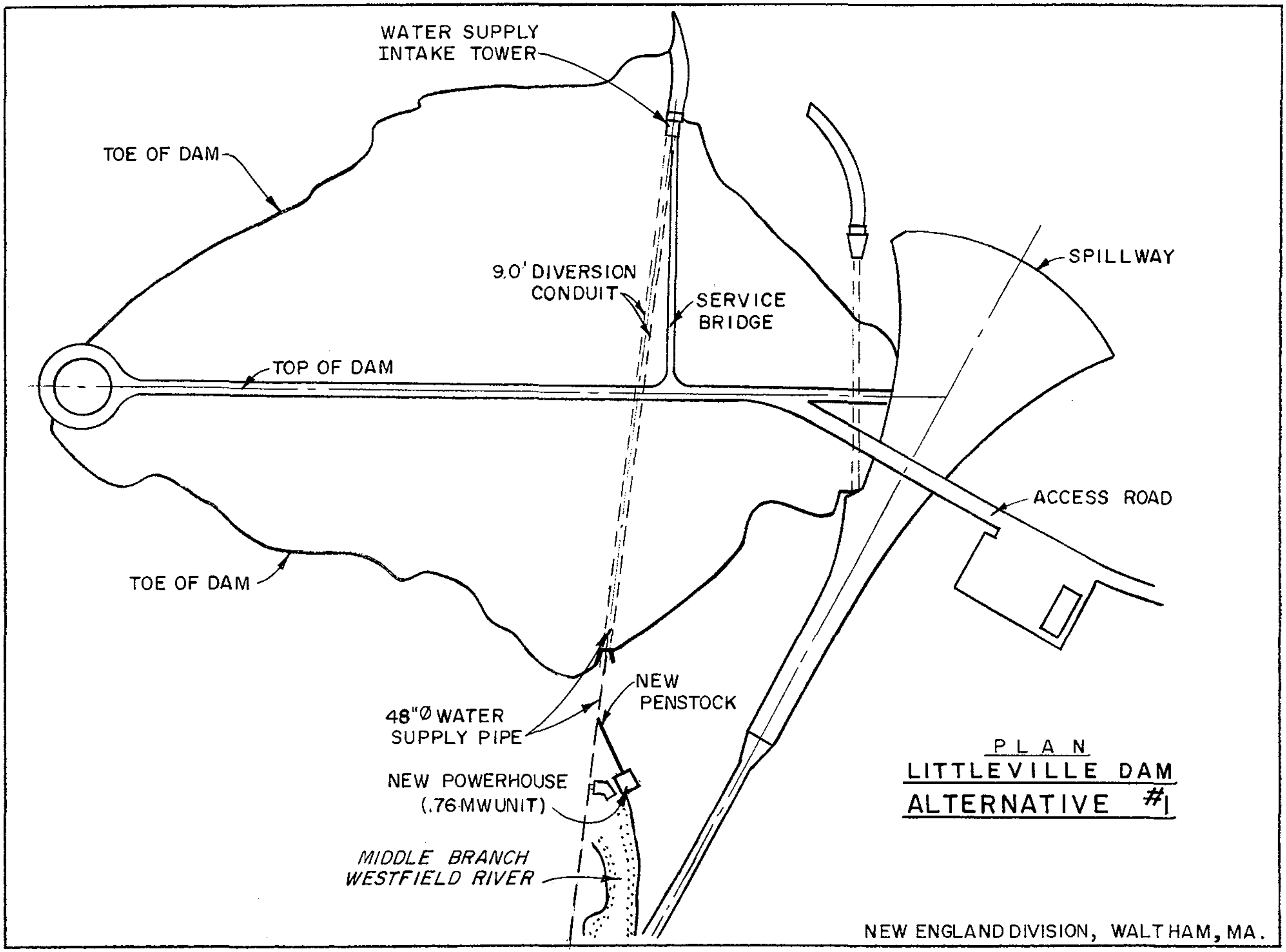
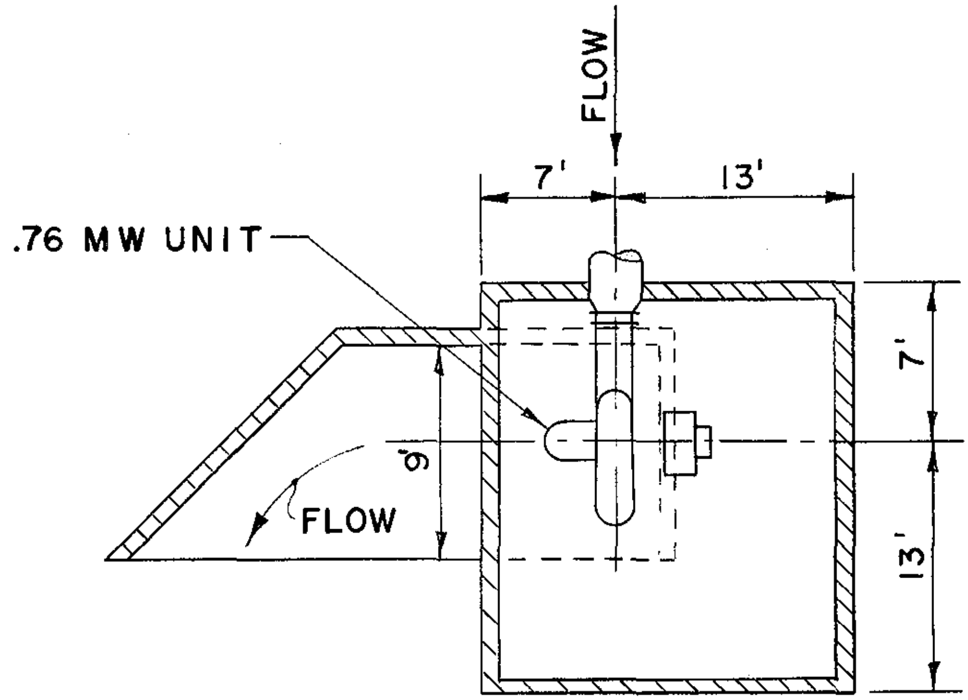
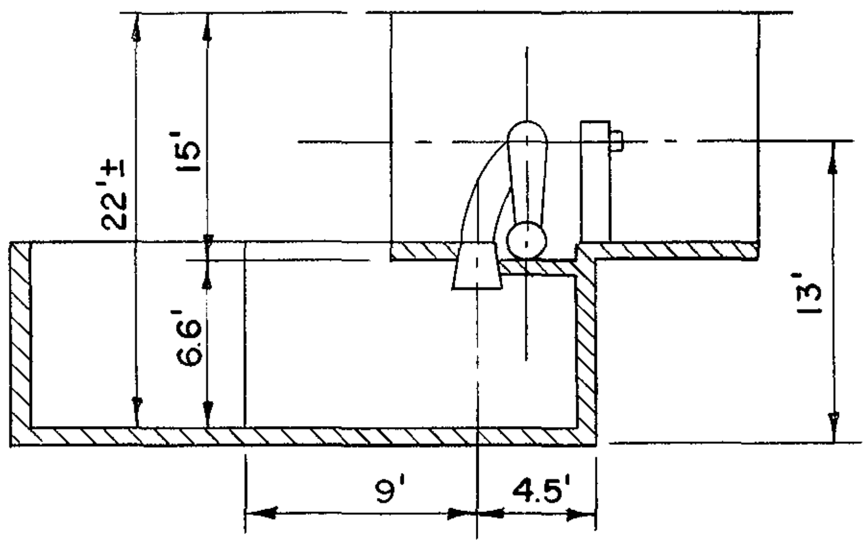

WATER SUPPLY
INTAKE TOWER
TOE OF DAM
9.0' DIVERSION
CONDUIT
SERVICE
BRIDGE
SPILLWAY
TOP OF DAM
ACCESS ROAD
TOE OF DAM
NEW
PENSTOCK
48"Ø WATER
SUPPLY PIPE
NEW POWERHOUSE
(.76 MW UNIT)
MIDDLE BRANCH
WESTFIELD RIVER
PLAN
LITTLEVILLE DAM
ALTERNATIVE #1
NEW ENGLAND DIVISION, WALTHAM, MA.

PLATE 11



PLAN



SECTION

POWERHOUSE

LITTLEVILLE DAM

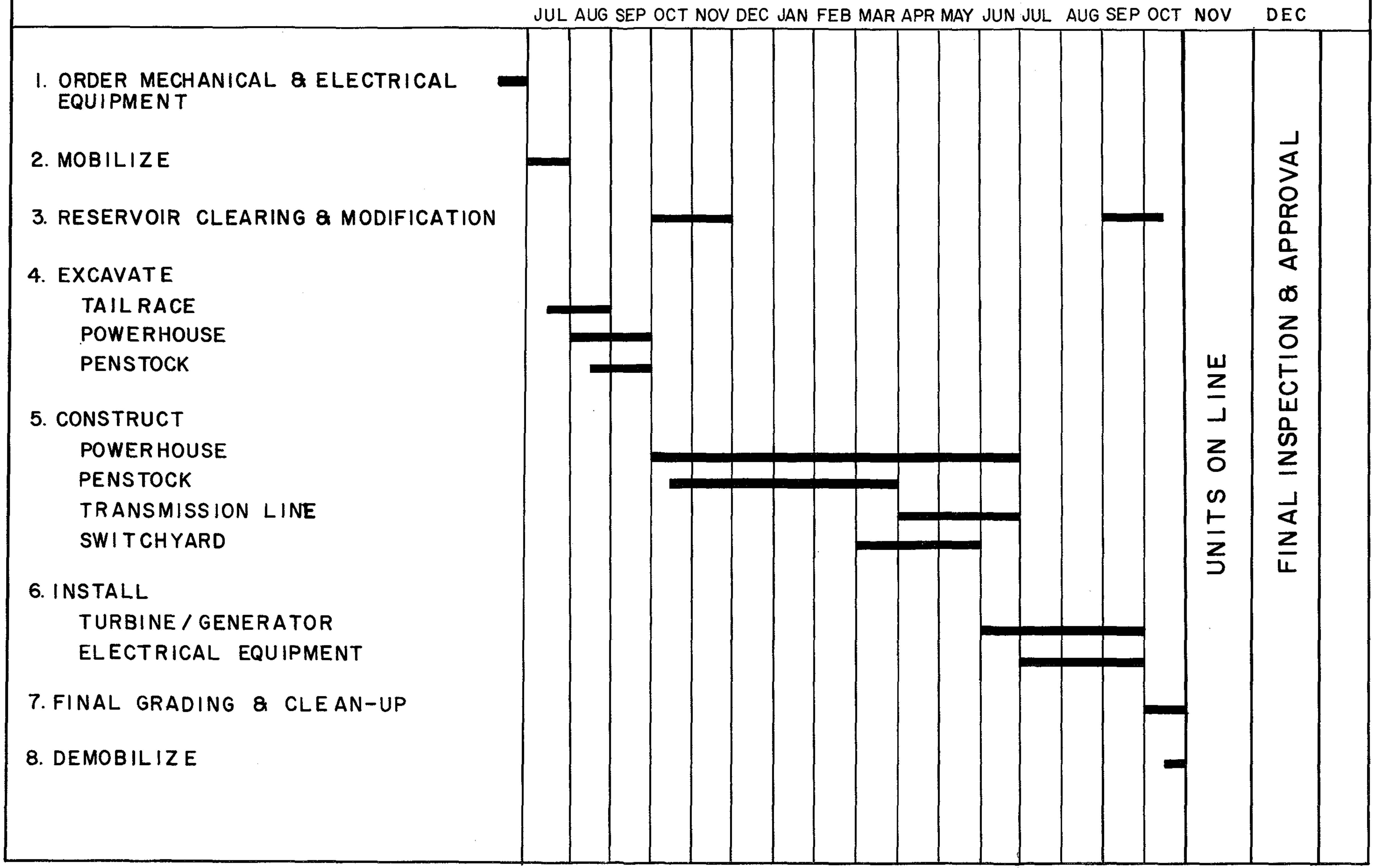
ALTERNATIVE #1

NEW ENGLAND DIVISION, WALTHAM, MA.

PLATE 12

NEW ENGLAND DIVISION, WALTHAM, MA.

CONSTRUCTION SCHEDULE
(LITTLEVILLE LAKE)



APPENDIX B - Water Supply Contract

CONTRACT BETWEEN THE UNITED STATES OF AMERICA
AND
THE CITY OF SPRINGFIELD
FOR
WATER STORAGE SPACE IN LITTLEVILLE RESERVOIR

THIS CONTRACT, entered into this 13th day of December, 1967, by and between the UNITED STATES OF AMERICA (hereinafter called the Government), represented by the Contracting Officer executing this contract, and THE CITY OF SPRINGFIELD, Massachusetts, (hereinafter called the City).

WITNESSETH THAT:

WHEREAS, the Flood Control Act of 1958 (72 Stat. 305) authorized the construction, operation, and maintenance of the Littleville Reservoir on the Middle Branch of the Westfield River, Massachusetts, (hereinafter called the "Project"); and,

WHEREAS, the City desires to contract with the Government for inclusion in the Project of storage for municipal and industrial water supply, and for payment for the cost thereof in accordance with the provisions of the Water Supply Act of 1958, as amended (43 USC 390 b-f); and,

WHEREAS, the City is empowered so to contract with the Government, and is vested with all necessary powers for accomplishment of the purposes of this contract.

NOW, THEREFORE, THE PARTIES DO MUTUALLY AGREE AS FOLLOWS:

ARTICLE 1. WATER STORAGE SPACE

a. Upon making the first payment on the principal for the water storage space, as provided in Article 4, the City shall have the right

(1) to utilize such storage space in the Project between Elevation 518.0 feet above mean sea level and 432.0 feet above mean sea level for water supply for municipal and industrial use as deemed necessary by the City,

(2) to impound water in the Project and make such diversions as granted to the City by the Commonwealth of Massachusetts to the extent that such storage will provide, and

(3) to withdraw water from the aforesaid storage space or to order releases therefrom to be made by the Government at any time so long as the elevation of the water in the reservoir is above Elevation 432.0 feet above mean sea level.

b. The Government reserves the right to take such measures as may be necessary in the operation of the Project to preserve life and/or property.

c. The City shall have the right to construct, operate, and maintain such installations or facilities at the Project as it may deem necessary for the purpose of diversions or withdrawals, subject to the approval of the Contracting Officer as to design and location. The City shall bear all costs of construction, operation, and maintenance or replacements of such installations and facilities.

d. The City recognizes that this contract provides storage space for raw water only. The Government makes no representation with respect to the quality or availability of water and assumes no responsibility therefor, and for treatment of the water.

ARTICLE 2. METERING

For the purpose of maintaining an accurate record of water resources at the Project, the City, prior to use of the water storage space, agrees to install suitable meters or metering devices satisfactory to the Contracting Officer, without cost to the Government. The City shall furnish the Government monthly statements of the quantity of water withdrawn.

ARTICLE 3. REGULATION OF THE USE OF WATER

The regulation of the use of water stored in the aforesaid storage space shall be the responsibility of the City. The City has the full responsibility to acquire in accordance with State laws and regulations, and if necessary to establish or defend, any and all water rights needed for utilization of the storage provided under this contract. The Government shall not be responsible for diversions by others, nor will it become a party to any controversies involving the use of storage space by the City, except as such controversies may affect the operations of the Government.

ARTICLE 4. CONSIDERATION AND PAYMENT

In consideration of the payments provided in this agreement to be paid by the City to the Government, the Government will provide storage space in the Project as provided in Article 1. In consideration of the Government providing the aforesaid storage space to the City, the City shall pay the following sums to the Government:

a. The sum of $2,202,160.48, which is the total estimated cost of providing water storage space, includes the amount of $173,079.00 for specific costs plus a percentage of the total joint-use cost amounting to $1,919,784.00 and interest during construction in the amount of $109,297.48. Payments shall be made in the following manner:

(1) A payment in the amount of $105,738.87 shall be made on 1 June 1968, and annually thereafter on 1 June of each year up to and including 1 June 1997. The date of 1 June 1968 is based on the assumption that the City will start drawing water on or about this date. The $105,738.87 is the annual payment necessary to liquidate the $2,202,160.48 estimate of cost of storage space in a period of 30 years with an interest rate of 2.742% per annum on the unpaid balance. In the event that the date of withdrawal of water is delayed beyond 1 June 1968, the schedule of payments for the storage shall be delayed to the same extent.

b. The aforesaid payments are more specifically set forth in Exhibit "B" attached hereto and made a part hereof, and the last payment of a.(1) above shall be adjusted upward and downward when due, to assure the repayment of all capital costs and interest within the 30-year period, in the following manner:

(1) In the event the actual first cost of the Project as finally determined exceeds the presently estimated first cost, the aforesaid annual payments shall be increased to reflect the actual first cost, including interest during construction, as determined by the Contracting Officer. In the event such first cost of the Project is less than the presently estimated first cost, the aforesaid annual payments shall be decreased to reflect the actual first cost, including interest during construction, as determined by the Contracting Officer.

(2) In the event the annual payments are increased or decreased, as provided above, an adjustment, as determined by the Contracting Officer, of payments made prior to the determination of the final Project cost shall be made in the first payment due after such costs are determined. At the time that the final Project costs are determined, Exhibit "B" shall be modified to reflect the increased or decreased annual payments and such modification will form a part of this contract.

c. No interest will be charged on the investment costs (construction costs plus interest during construction) allocated to the water supply until use is initiated, but such interest-free period shall not exceed ten years. If use is not initiated until after September 1975, (ten years from the time the project was completed and available for water supply services) the interest at the rate of 2.742% from the tenth year until use is initiated may, at the option of the City, be paid annually in order to avoid the long term cumulative effects of such interest. If the interest is not paid annually, the interest from the tenth year until use is initiated will be compounded annually and added to the investment costs to be repaid.

d. The City shall have the right at any time it so elects to prepay its indebtedness under Article 4a in whole or in part; with accrued interest thereon to the date of such prepayment.

e. <u>The annual experienced joint use cost of ordinary operation and maintenance of the project allocated to water supply</u>.

(1) The first payment estimated to be $9,242. will be due and payable when water supply is utilized and payments are initiated; presently estimated to be 1 June 1968 Annual payments will be due and payable in advance on the first day of June thereafter and will be equal to the allocated portion of the actual experienced joint use cost of ordinary operation and maintenance and replacement costs for the preceding Government fiscal year. The second payment shall be increased or decreased in an amount to reflect the difference between the first payment and the actual allocated portion of the experienced joint use cost of ordinary operation and maintenance and replacement costs for the preceding fiscal year. The joint use costs shall be allocated on the basis of 70 percent to the Government and 30 percent to the City.

(2) Records of cost of operation and maintenance of the Project shall be available for inspection and examination by the City. However, the extent of operation and maintenance of the Project shall be determined by the Contracting Officer and all records and accounting shall be maintained by the Contracting Officer.

f. The City shall pay 100% of the cost of specific major capital replacements for the water supply facilities, and 30 percent of the cost of joint-use major capital replacement items and sedimentation resurveys, when incurred. Payment shall be made with the first annual payment becoming due after the date said cost is incurred.

g. In the event of default in the payment of the costs contained in Article 4, a through f, the amount of such payments shall be increased by an amount equal to interest on such overdue payments at the rate of two and seven hundred forty-two thousandths per cent (2.742%) per annum thereon; compounded annually, and such amount equal to interest shall be charged from the date such payments are due until paid.

ARTICLE 5. <u>PERIOD OF CONTRACT</u>

This contract shall become effective as of the date of approval by the Secretary of the Army and shall continue in full force and effect under the conditions set forth herein not to exceed the life of the project.

ARTICLE 6. <u>PERMANENT RIGHTS TO STORAGE</u>

Upon completion of payments by the City, as provided in Article 4 herein, the City shall have a permanent right under the provisions of P.L. 88-140 to the use of such storage space in the project, as provided in Article 1 herein, subject to the following:

a. The City must have discharged its responsibilities for payment of the costs allocated to water supply.

b. The City must continue payment of annual operation and maintenance costs allocated to water supply.

c. The City shall bear the costs allocated to water supply of any necessary reconstruction, rehabilitation or replacement of Project features which may be required to continue satisfactory operation of the Project. Such costs will be established by the Contracting Officer. Repayment arrangements including schedules will be in writing and will be made a part of this contract.

d. Upon completion of payments by the City, as provided in Article 4.a. above, the Contracting Officer shall redetermine the storage space for municipal and industrial water supply, taking into account such equitable reallocation of reservoir storage capacities among the purposes served by the project as may be necessary due to sedimentation. Such findings, and the storage space allocated to municipal and industrial water supply shall be defined and described in an exhibit which will be made a part of this contract by supplemental agreement. Following the same principle, such reallocation of reservoir storage capacity may be further adjusted from time to time as the result of sedimentation resurveys to reflect actual rates of sedimentation and the exhibit revised to show the revised storage space allocated to municipal and industrial water supply.

e. The permanent rights of the City shall be continued so long as the Government continues to operate the project. In the event the Government no longer operates the project, such rights may be continued subject to the execution of a separate contract, or supplemental agreement providing for:

(1) Continued operation by the City of such part of the facility as is necessary for utilization of the storage space allocated to it;

(2) Terms which will protect the public interest;

(3) Effective absolvement of the Government by the City from all liability in connection with such continued operation.

ARTICLE 7. OPERATION AND MAINTENANCE

The Government shall maintain and operate the Project owned by the Government. The City shall have the right to make withdrawals of water for its purposes, as needed, in accordance with Article 1. The City shall be responsible for operation and maintenance of all features and appurtenance which may be provided and owned by the City.

ARTICLE 8. TRANSFER AND ASSIGNMENT

The city shall not transfer or assign this contract, nor any rights acquired thereunder, nor suballot said water or storage space or any part thereof, nor grant any interest, privilege or license whatsoever in connection with this contract, without approval of the Secretary of the Army or his authorized representative; provided that this restriction shall not be construed to apply to any water which may be obtained from the water supply storage space by the City and furnished to any third party or parties.

ARTICLE 9. RELEASE OF CLAIMS

The City shall hold and save the Government, including its officers, agencies, and employees, harmless from liability of any nature or kind for, or on account of, any claim for damages which may be filed or asserted as a result of the water supply storage in the Project, or withdrawal or release of such water from the Project, made or ordered by the City, or as a result of the construction, operation, or maintenance of the appurtenances owned and operated by the City.

ARTICLE 10. FEDERAL AND STATE LAWS

The City shall utilize such storage space in a manner consistent with Federal and State laws.

ARTICLE 11. OFFICIALS NOT TO BENEFIT

No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of this contract, or to any benefit that may arise therefrom, but this provision shall not be construed to extend to this contract if made with a corporation for its general benefit.

ARTICLE 12. COVENANT AGAINST CONTINGENT FEES

The City warrants that no person or selling agency has been employed or retained to solicit or secure this contract upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies maintained by the City for the purpose of securing business. For breach or violation of this warranty the Government shall have the right to annul this contract without liability or in its discretion to add to the contract price or consideration, or otherwise recover, the full amount of such commission, percentage, brokerage, or contingent fee.

ARTICLE 13. APPROVAL OF CONTRACT

This contract shall be subject to the written approval of the Secretary of the Army and shall not be binding until so approved.

IN WITNESS WHEREOF, the parties hereto have executed this contract as of the day and year first above written.

THE UNITED STATES OF AMERICA

By Remi O. Renier
REMI O. RENIER
Colonel, Corps of Engineers
Division Engineer
Contracting Officer

TWO WITNESSES:

John W. Curran
Name

101 Mulberry St
Springfield, Mass.
Address

George E. Sweeney
Name

33 Kittrell Street
Spfld, Mass. 01119
Address

THE CITY OF SPRINGFIELD
BOARD OF WATER COMMISSIONERS

Frank H. Freedman
Mayor

Spiros G. Manolakis
Chairman

Carson [illegible]
Member

CORPORATE SEAL

APPROVED:

Stanley R. Resor
SECRETARY OF THE ARMY

DATE:

CERTIFICATE

I, William C. Sullivan, do hereby certify that I am City Clerk of the City of Springfield of the Commonwealth of Massachusetts named herein; that Frank H. Freedman who signed this contract on behalf of the City of Springfield was then and there the duly elected and qualified Mayor of the City of Springfield, that Spiros G. Manolakis who signed this contract as the Chairman, Board of Water Commissioners, was then and there the duly elected and qualified Chairman, Board of Water Commissioners, and that Carson H. Cluley who signed this contract as the Member of the Board of Water Commissioners was then and there the duly appointed and qualified Member of the Board of Water Commissioners, that said contract was duly signed for and on behalf of the City of Springfield and the Board of Water Commissioners by virtue of their authority as Mayor and the Board of Water Commissioners, respectively, and are within the scope of their and the City's statutory powers.

IN WITNESS WHEREOF, I have hereunto affixed my hand and the seal of the City of Springfield the 1st day of February 1968. ~~1967~~.

William C. Sullivan

City Clerk

William C. Sullivan

CITY SEAL

~~APPROVED:~~

~~SECRETARY OF THE ARMY~~

~~BY:~~

EXHIBIT A

I - RESERVOIR STORAGES

Feature	Elevation (ft. msl)	Storage (ac-ft)	Percent
Flood Control	518 to 576	23,000	71.00
Water Supply	432 to 518	9,400	29.00
Total		32,400	100.00

II - ALLOCATION OF PROJECT INVESTMENT COST

Flood Control	$5,058,637.57
Water Supply	2,202,160.48
Total	$7,260,798.05

III - PROJECT COSTS ALLOCATED TO CITY OF SPRINGFIELD

Cost of 9,400 acre-feet of water supply storage $2,202,160.48

IV - ALLOCATION OF ESTIMATED OPERATION & MAINTENANCE COST

WATER SUPPLY

	City of Springfield $	Flood Control $	Total $
Specific Cost	---	7,095	7,095
Joint Cost	9,242	21,563	30,805
Total	$9,242	$28,658	$37,900

V - ALLOCATION OF ESTIMATED ANNUAL CHARGES FOR MAJOR REPLACEMENTS

WATER SUPPLY

	City of Springfield $	Flood Control $	Total $
Specific Cost	1,245	1,399	2,644
Joint Cost	49	119	168
Total	$1,294	$1,518	$2,812

VI - ANNUAL CHARGES TO CITY OF SPRINGFIELD

Interest and amortization of cost of water supply feature (1)	$105,738.87
24.385 percent of the actual operation and maintenance cost for the preceding fiscal year; computed as follows:	
$\frac{9,242}{37,900} \times 100 = 24.385\%$ Estimated annual amount	9,242.00
29.167 percent of the joint-use cost of major replacement and sedimentation resurveys, when incurred, computed as follows:	
$\frac{49}{168} \times 100 = 29.167\%$ Estimated annual amount	49.00
Total (Estimated)	$115,029.87

(1) Based on 30 payments, 29 of which bear interest on the unpaid balance at rate of 2.742 percent; computed as follows:

$$D = \frac{R}{1 + \cfrac{1}{\left(i + \cfrac{i}{(1+i)^{n-1} - 1} \right)}}$$

WHEREIN:

D = annual payment
R = amount to be repaid $2,202,160.48
i = interest rate 2.742
n = number of payments 30

OR:

$$D = \frac{\$2,202,160.48}{1 + \cfrac{1}{\left(.02742 + \cfrac{.02742}{(1 + .02742)^{29} - 1} \right)}}$$

which = $2,202,160.48 x .048016 =

$105,738.87

EXHIBIT B

Amortization Schedule

Cost of Water Supply for the City of Springfield

TOTAL COST	$2,202,160.48
NUMBER OF PAYMENTS	30
INTEREST RATE, PERCENT	2.742

ANNUAL PAYMENT NO.	AMOUNT OF PAYMENT	APPLICATION INTEREST	APPLICATION ALLOC. COST	BALANCE ALLOC. COST
	$	$	$	$
				2,202,160.48
1	105,738.87	0	105,738.87	2,096,421.61
2	105,738.87	57,483.88	48,254.99	2,048,166.62
3	105,738.87	56,160.73	49,578.14	1,998,588.48
4	105,738.87	54,801.30	50,937.57	1,947,650.91
5	105,738.87	53,404.59	52,334.28	1,895,316.63
6	105,738.87	51,969.58	53,769.29	1,841,547.34
7	105,738.87	50,495.23	55,243.64	1,786,303.70
8	105,738.87	48,980.45	56,758.42	1,729,545.28
9	105,738.87	47,424.13	58,314.74	1,671,230.54
10	105,738.87	45,825.14	59,913.73	1,611,316.81
11	105,738.87	44,182.31	61,556.56	1,549,760.25
12	105,738.87	42,494.43	63,244.44	1,486,515.81
13	105,738.87	40,760.26	64,978.61	1,421,537.20
14	105,738.87	38,978.55	66,760.32	1,354,776.88
15	105,738.87	37,147.98	68,590.89	1,286,185.99
16	105,738.87	35,267.22	70,471.65	1,215,714.34
17	105,738.87	33,334.89	72,403.98	1,143,310.36
18	105,738.87	31,349.57	74,389.30	1,068,921.06
19	105,738.87	29,309.82	76,429.05	992,492.01
20	105,738.87	27,214.13	78,524.74	913,967.27
21	105,738.87	25,060.98	80,677.89	833,289.38
22	105,738.87	22,848.79	82,890.08	750,399.30
23	105,738.87	20,575.95	85,162.92	665,236.38
24	105,738.87	18,240.78	87,498.09	577,738.29
25	105,738.87	15,841.58	89,897.29	487,841.00
26	105,738.87	13,376.60	92,362.27	395,478.73
27	105,738.87	10,844.03	94,894.84	300,583.89
28	105,738.87	8,242.01	97,496.86	203,087.03
29	105,738.87	5,568.65	100,170.22	102,916.81
30	105,738.87	2,821.98	102,916.81	0.00

LITTLEVILLE RESERVOIR

TOTAL CONSTRUCTION COST AND ALLOCATION

OF INTEREST DURING CONSTRUCTION

Water Supply	Construction Cost	Interest During Construction	Total Cost
Specific Costs	$ 173,079.00	$ 6,939.59	180,018.59
Allocation of Joint Use Cost	1,919,784.00	102,357.89	2,022,141.89
	$2,092,863.00	$109,297.48	$2,202,160.48
Flood Control			
Specific Costs	$ 108,905.00	$ 1,004.98	$ 109,909.98
Allocation of Joint Use Costs	4,697,880.00	160,195.48	4,858,075.48
	$4,806,785.00	$161,200.46	$4,967,985.46
Recreation Facilities			
Specific Cost	$ 90,641.00	$ 11.11	$ 90,652.11
		Total	$7,260,798.05

ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

The CITY OF SPRINGFIELD, MASSACHUSETTS (hereinafter called "Applicant-Recipient")

HEREBY AGREES that it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from the Department of the Army and HEREBY GIVES ASSURANCE THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by this Department of the Army assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof, to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The

Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

DATED May 13, 1968

CITY OF SPRINGFIELD, MASSACHUSETTS
(Applicant-Recipient)

BY
(Chairman, Board of Water Commissioners)

(Member, Board of Water Commissioners)

(Mayor)

CITY OF SPRINGFIELD, MASSACHUSETTS
36 Court Street or
P. O. BOX 1867, Springfield, Mass. 01103
(Applicant-Recipient's Mailing Address)

Attest:

City Clerk

DEFINITIONS AND TERMS

BRITISH THERMAL UNIT (BTU) - The standard unit of measurement for determining the amount of heat energy or heat content of a fuel. One BTU is equal to the amount of heat energy necessary to raise the temperature of one pound of water one degree Fahrenheit, at or near 39.2° F.

CAPACITY - The maximum power output or load for which a turbine-generator, station or system is rated.

DEMAND - The rate at which electric energy is delivered to or by a system, part of a system, or piece of equipment, usually expressed in kilowatts or megawatts, for a particular instant or averaged over a designated period of time.

DEPENDABLE CAPACITY - The load carrying ability of a hydropower plant under adverse hydologic conditions for the time interval and period specified of a particular system load.

DRAWDOWN - The distance that the water surface elevation of a storage reservoir is lowered from a given or starting elevation as a result of the withdrawal of water to meet some project purpose (i.e., power generation, creating flood control space, irrigation demand, etc.).

ENERGY - The capacity for performing work. The electrical energy term generally used is kilowatt-hours and represents power (kilowatts) operating for some time period (hours).

FIRM ENERGY - The energy generation ability of a hydropower plant under adverse hydrologic conditions for the time interval and period specified of a particular system load.

GENERATOR - A machine which converts mechanical energy into electric energy.

GROSS HEAD - The difference in water surface elevation as measured in the forebay and tailrace of a hydropower plant, under certain specified conditions. Usually, gross head refers to the difference between normal full pool and average tailwater elevations.

HYDRAULIC CAPACITY - The maximum flow which a hydroelectric power plant can utilize for the generation of electricity.

HYDROELECTRIC PLANT or HYDROPOWER PLANT - An electric power plant in which the turbine/generators are driven by falling water.

INSTALLED CAPACITY - The total of the capacities shown on the nameplates of the generating units in a hydropower plant.

INTERRUPTIBLE POWER - Non-firm power; power made available under agreements which permit curtailment or cessation or delivery by the supplier. Interruptible power loads are normally met with secondary hydro energy.

KILOWATT (Kw) - One Thousand watts.

KILOWATT-HOUR (Kwh) - The amount of electrical energy involved with a one-kilowatt demand over a period of one hour. It is equivalent to 3,413 BTU of heat energy.

LOAD - The amount of power needed to be delivered at a given point on an electric system.

MEGAWATT (Mw) - One thousand kilowatts.

MEGAWATT-HOURS (Mwh) - One thousand kilowatt-hours.

NET HEAD - Also called effective head. The gross head less all hydraulic losses except those chargeable to the turbine.

OUTPUT - The amount of power or energy delivered from a piece of generating equipment or a generating station.

PENSTOCK - A conduit used to convey water under pressure, to the turbines of a hydroelectric plant.

PLANT FACTOR - Ratio of the average load to the plants installed capacity, expressed as an annual percentage.

POWER (ELECTRIC)- The rate of generation or use of electric energy, usually measured in kilowatts.

RUN-OF-RIVER PLANT - A hydroelectric generating plant which depends chiefly on the flow of a stream or river as it occurs for generation purposes, as opposed to a storage project, which has sufficient storage capacity to carry water from one season to another. Some run-of-river projects have a limited storage capacity (poundage) which permits them to regulate streamflow on a daily or weekly basis.

SPINNING RESERVE - Generating units operating at no load or at partial load with excess capacity readily available to support additional load.

STANDBY RESERVE - Generating equipment or other facilities reserved for use in case of outages or other emergency operating conditions. The generating equipment and other facilities may or may not be in service normally. This category of reserve should not be confused with spinning reserve.

SYNCHRONIZED OPERATION - An operation wherein electrical generating facilities are electrically connected and controlled to operate at the same frequency. It is synonymous with operation in parallel.

TAILWATER - The water surface elevation immediately downstream from a dam or hydroelectric power plant. A high tailwater condition reduces the hydraulic head and thus the efficiency of a hydroelectric generating station.

THERMAL PLANT - A generating plant which uses heat to produce electricity. Such plants may burn coal, gas, oil or use nuclear energy to produce thermal energy.

TRANSMISSION - The act or process of transporting electric energy in bulk.

TRANSMISSION GRID - An interconnected system of electric transmission lines and associated equipment for the movement or transfer of electrical energy in bulk between points of supply and points of demand.

TURBINE - The part of a generating unit which is spun by the force of water or steam to drive an electric generator. The turbine usually consists of a series of curved vanes or blades on a central spindle.

ACKNOWLEDGEMENTS

The New England Division, U.S. Army Corps of Engineers prepared this report under the direction of Col. Max B. Scheider, Division Engineer; Joseph L. Ignazio, Chief of the Planning Division; and Harmon H. Guptill, Chief, Hydroelectric Energy Studies Branch.

Investigations were performed by an interdisciplinary project team. Those persons primarily responsible for the contents of this report are: Richard DeSimone - Project Manager, David Tomey - environmental analysis, Farrell McMillan - hydrologic engineering, James O'Leary - layout and design, Richard Ring - economic analysis, Douglas Cleveland - recreation, John Wilson - cultural aspects, Diana Platt - socioeconomic, Paul L'Heureux and Eugene Brickman - geotechnical engineering and David Buelow-water quality.

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